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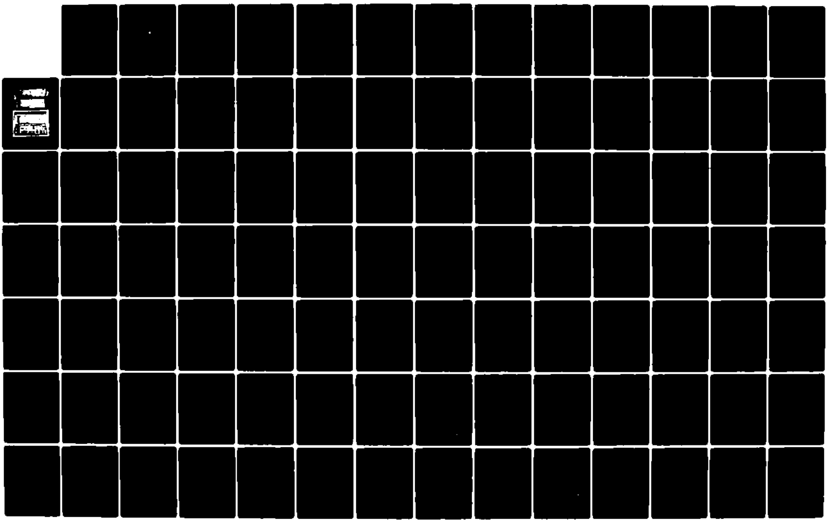

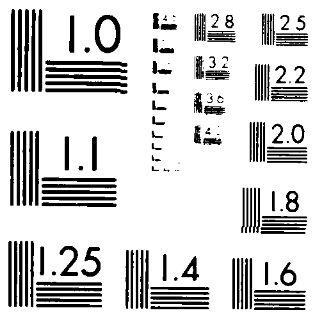

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

ANALYSIS AND TESTING OF THE THERMAL DESIGN
OF THE ELECTRONIC PACKAGE IN THE U.S. ARMY'S
UPGRADED LOGIC MODULE (ULM)

by

Henry C. Keebler III

September 1983

Thesis Advisor: M. Kelleher

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20. ABSTRACT (Continued)

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Analysis and Testing of the Thermal Design of the Electronic Package in the U.S. Army's Upgraded Logic Module (ULM)

by

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ABSTRACT

The U.S. Army has developed an Upgraded Logic Module (ULM) for use in its Infantry Direct Fire Simulator System (IDFSS). It is designed to analyze data collected from associated instrumentation according to prescribed programming, to report results back to the system control via a telemetry interface, and it can be backpack mounted.

The thermal environment existing at Ft. Hunter Liggett, Ca. (the primary operating environment for the ULM) during the summer will add an abnormal thermal load to the ULM operating environment in the backpack.

A mock-up of the actual ULM was built to model the heat dissipation of all the components and tested in different environments using extreme power consumption rates. The actual ULM was tested with typical power consumption rates and various environmental temperatures, including solar loading. Under typical operating conditions, the ULM will remain within manufacturer's tolerances for individual component temperatures. However slight increases in power consumption rates will severely stress the reliability limits of certain components, and the reliability of the entire system cannot be predicted.

TABLE OF CONTENTS

LIST OF FIGURES

I. INTRODUCTION

A. BACKGROUND OF THE ULM

The U.S. Army Combat Developments Experimentation Command (CDEC), conducts combat experiments at Ft. Hunter Liggett, California, often involving infantry and vehicle players in mock battle. These experiments are designed to test various weapons systems, strategies, vehicles, and personnel under equally varied conditions.

Players are generally instrumented to monitor the battle activity and are linked to a main computer system via telemetry devices. The instrumentation utilized must operate under dusty conditions, high vibration, and in temperatures ranging from 10 fahrenheit in the winter to 120 fahrenheit in the summer.

Prior to the experiment, player instrumentation is planned and designed to fit the particular parameters of the experiment. Maximum use of existing equipment is planned whenever possible. However, due to the uniqueness of many of the experiments--in terms of equipment and scope--new devices, cables, and mounting hardware must be designed or existing inventory modified. For these reasons and due to the high frequency of new experiments, there is a constant process of upgrading and re-designing existing equipment to meet the needs of the current experiment--with little regard given to the uses for future requirements.

The unfortunate consequences of this type of design process are many:

- Existing hardware--although functionally adequate--may not be compatible with other existing hardware.
- Due to modifications, documentation is often poor and usually only addresses the experiment of the original design.
- These poorly designed functional modules are extremely difficult for new personnel to use in the planning of new experiments.
- Finally, much of the equipment has become obsolete and hard to maintain.

For these reasons CDEC has developed the Upgraded Logic Module (ULM) to replace the Logic Module of the Infantry Direct Fire Simulator System. The objectives of the ULM design are:

- Support the infantry player with minimum size and weight, yet allow expansion of functions where size and weight are not critical.
- Fit the existing backpack.
- Use a microprocessor such that the inherent flexibility of the program memory can be used to meet future requirements without re-design.
- Provide input and output interfaces with sufficient flexibility to support the diverse player configurations.
- Be compatible with existing units and cables to the maximum possible extent.
- Use conventional packaging techniques to simplfy parts procurement, assembly, maintenance, and repair.
- Provide hermetic sealing to protect against dust.
- Provide general purpose bus interfaces for adding other developed equipment.

- Partition the hardware and firmware into sharply defined functional modules to make the design easier to understand, to simplify the documentation, and to provide the ability to meet future requirements by redesigning a module instead of the entire ULM [Ref. 1].

B. OBJECTIVES

The thermal characteristics of the ULM were a prime consideration during the design process. Components chosen were specifically required to be capable of operation in the high temperature of the ULM. It was recognized that the small size of the ULM and the large number of integrated circuits could challenge the stress limits of current micr electronic packaging techniques [Ref. 2]. Additionally th high ambient temperatures existing at Ft. Hunter Liggett during the summer months would place an additional thermal load on the ULM which cannot be accurately predicted.

Thus the purpose of this test and analysis is to check the thermal performance of the ULM. Specifically tests were designed to:

- Determine if the ULM operating under typical conditions of power consumption and environment would remain within the reliability limits specified by manufacturers for their individual components.

- Attempt to predict performance under off-design conditions.

Using resistors to produce the heating characteristics of the individual internal components, a model was designed and constructed to simulate the power dissipation of the actual ULM. To accomplish the above objectives, both the model and the ULM were instrumented with thermocouples to measure temperatures at specific locations and on specific components.

C. DEVICE DESCRIPTION

The Upgraded Logic Model (ULM) is an integral part of the Infantry Direct Fire Simulator System (IDFSS) responsible for the collection of data from infantrymen instrumented in connection with a combat development experiment. It analyzes data according to its programming for that experiment and reports results via a telemetry interface back to the system control computer center.

The ULM consists of two circuit boards housed in a machined cast aluminum case with outside dimensions of 1.75x5x10 in. The circuit boards are made of multi-layered glass epoxy and copper circuits. The fully populated boards and case weigh approximately five pounds. Its power consumption is rated at a maximum of 15 watts at 5 volts, with a typical usage of 7 to 9 watts at 5 volts [Ref. 3].

The case is made of two separate halves, each containing one of the circuit boards and one of the connectors shown in Figure 1.1. The half containing the J1 connector houses the CPU board, and the one containing the J2 connector houses the I/O board. The two boards are connected by a fifty pin ribbon connector, and when the two halves are assembled, the tops of the components from each board face each other. The

Figure 1.1   MODEL(top) AND ULM(bottom).

boards are fastened by 12 hex head machine screws with a gasket between the two halves of the case for dust protection.

The circuitry consists of a Central Processing Unit (CPU) Board and an Input/Output (I/O) Board, depicted in Figures 1.2 and 1.3. The CPU Board contains over 60 separate electronic components, including the Z8002 16 bit CPU(u3).

The I/O Board also contains approximately 60 electronic components, including two Z-8 Micro-computer processors (u2,u11) and the ZCIO I/O chips(u1). The larger socket mounted dual-in-line pin (DIP) devices are listed in Tables 1 and 2, and are shown in Figures 1.2 and 1.3. All components are rated by the manufacturer for maximum case temperature tolerances to 125 C, except the following devices:

u3 of the CPU

u1,u2,u11,u12, and u13 of the I/O

which are rated at 85 C.

The ULM is equipped with two connectors, one for power input and the other for I/O signals and testing. For this evaluation, the ULM was specially wired to give typical power consumption rates for the system without using the I/O connector. This allowed an I/O connector midification to accommodate the many thermocouple wires to be inserted into the case. However this also prevented the ULM from being tested under atypical power consumption rates.

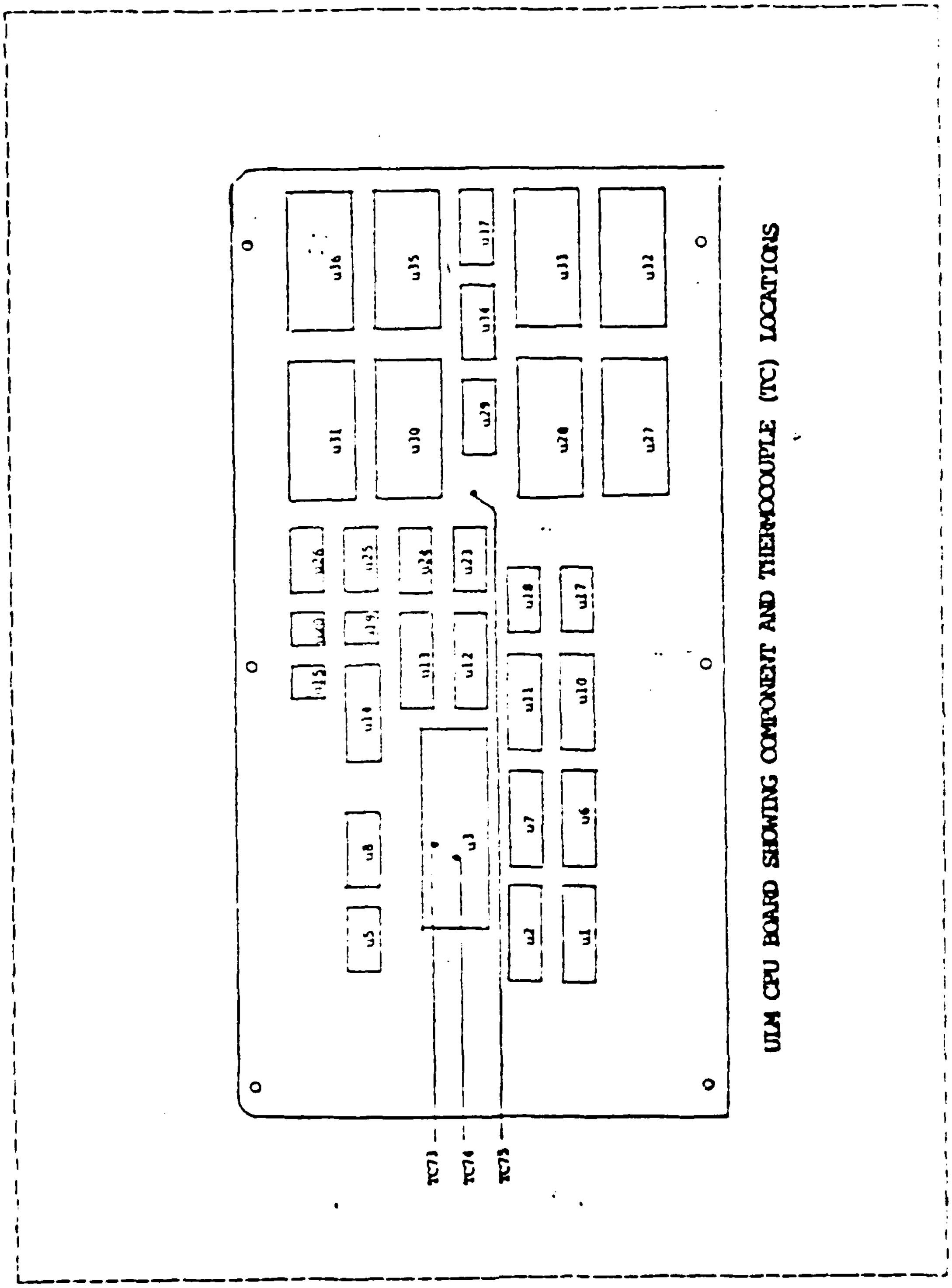

Figure 1.2   CPU BOARD.

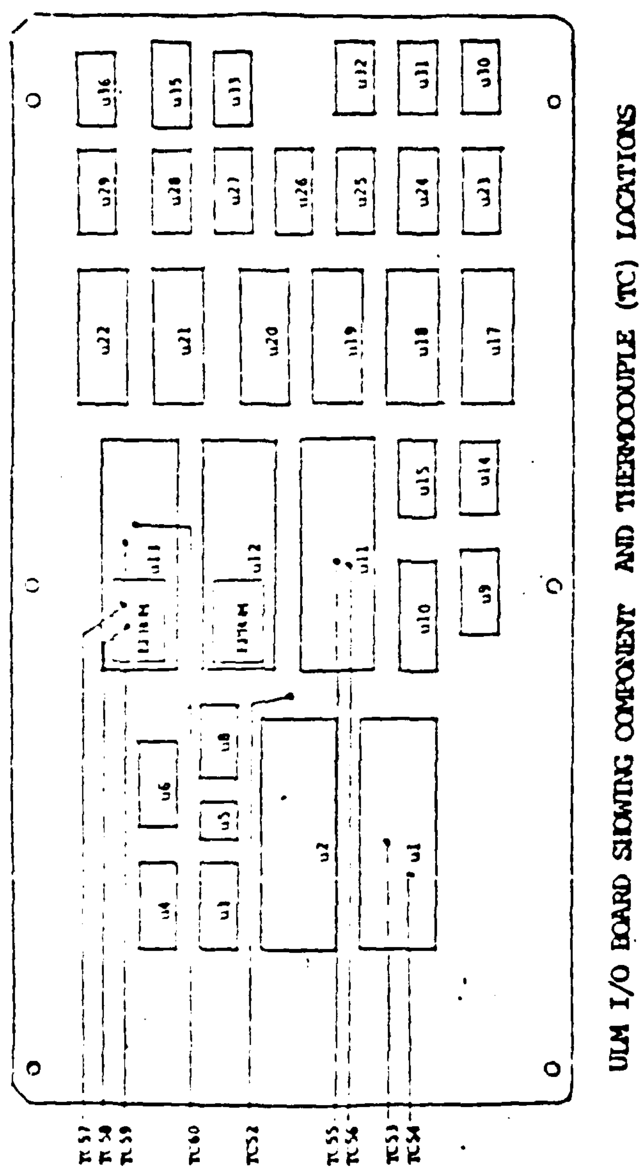

Figure 1.3 I/O BOARD.

TABLE 1

CPU MODEL DATA

UNIT	I(ma)	R(ohms)	POWER(w)
1	90	55.55	.45
2	90	55.55	.45
3	300	16.67	1.5
5	10	500.	.05
6	50	100.	.25
7	50	100.	.25
8	30	166.67	.15
10	90	55.	.45
11	90	55.	.45
12	40	125.	.20
13	120	41.66	.60
14	40	125.	.20
15-23	0	0	0
24	7	714.29	.04
25	6	833.33	.03
26	0	0	0
27	10	500.	.05
28	60	83.3	.30
29	0	0	0
30	60	83.3	.30
31	90	55.55	.45
32	10	500	.05
33	60	83.3	.3
34	0	0	0
35	60	83.3	.3
36	90	55.55	.45
37	0	0	0
38	40	125.	.2

TABLE 2

I/O MODEL DATA

UNIT	I(ma)	R(ohms)	POWER(w)
1	250	20.0	1.25
2	250	20.0	1.25
3	0	0	0
4	0	0	0
5	50	100.	.25
6	0	0	0
8	0	0	0
9	26	192.3	.13
10	120	41.67	.60
11	250	20.	1.25
12	180	27.7	.90
13	180	27.7	.90
14-27	0	0	0
29	80	62.5	.40
30	54	92.6	.27
31	54	92.6	.27
32-36	0	0	0

II. TEST PROCEDURE

A. PRELIMINARY SETUP

Test procedures for the ULM and the model were determined by various limitations--primarily equipment availability and facilities. Initially, the actual ULM was not available for testing, and a model was presumed to be the primary vehicle for this analysis.

The questions were:

- How to fabricate the model to simulate the thermal characteristics of the ULM?
- How to instrument the individual components?
- How to simulate the various conditions under which the ULM would operate?

The last two questions also applied to the actual ULM when it was learned one would be available for testing. Fortunately, most of the solutions to these problems were equally applicable to the ULM, with only some modification.

Using an actual ULM case, two unpopulated ULM circuit boards, the ULM technical drawings, and power consumption rates--which were all provided by CDEC--the model was fabricated. To simulate the individual components in terms of thermal energy dissipation, resistors were used as heaters and scaled to the component's power dissipation rate shown in Tables 1 and 2. For most of the DIP components with 16 pins or less, DIP resistor networks were wired to meet the calculated resistance required and then mounted into DIP sockets. Required resistances shown in Tables 1 and 2, were calculated based on power consumption rates of individual components at 5 volts. Using the relation:

power = current * voltage

the current was calculated, and using Ohm's Law:

voltage = current * resistance

an equivalent resistance was calculated for each component. For DIP components with more than 16 pins, the DIP resistor networks were not readily available. Therefore similar resistor networks were fabricated using single resistors wired into DIP adapters, forming an equivalent resistor network. Covers were added to these heaters to simulate a more even heat dissipation on the surface of the component, and to maintain geometric similitude. Each component was then placed in the exact position on the board as occupied by its actual counterpart.

Before beginning model fabrication, the decision to use type-T thermocouples for temperature measurement was made. As the critical temperatures for all components were well within the range of the type-T (copper constantan) thermocouples, and the thermocouple wire and connectors were readily available, this was a logical choice. Due to the small area of consideration and to minimize disturbances to the internal natural convection of the air, 30 gauge wire was chosen for fabricating the thermocouples.

Next a determination was made concerning which specific components were to be instrumented. This was based on elements with the lowest critical temperatures and the highest heat dissipation from Tables 1 and 2. Additionally, thermocouples were placed on the boards, in the air gap between the boards, and on the inside and outside of the case to determine the various thermal resistances of the heat flow path. These locations are listed in Tables 3, 4, and 5 and shown in Figures 1.2, 1.3, 2.1, and 2.2. The thermocouples were fabricated in lengths of approximately 24 in. and connected to 15 ft. lengths of type T thermocouple extension wire.

The thermocouples were then calibrated using the HP 3054 Data Acquisition System and the Rosemount calibration bath (see Appendix B). Two D-style 50 pin connectors used on the ULM were also used on the model. One was used to provide power to the unit, while the other was modified and used as a passageway for the thermocouple wires. The modification was accomplished by drilling out 8 of the pins in the center of the connector with space to accommodate the bundle of thermocouple wires. A slit large enough for one wire was cut in the top of the connector to the hole to facilitate the removal and insertion of the thermocouple

Table 3

MODEL I/O BOARD THERMOCOUPLES (TC)

TC	COMPONENT/LOCATION
61	u2 bottom
62	u2 top
63	u1 bottom
64	u1 top
65	u10 top
66	u10 bottom
67	u11 bottom
68	u11 top
69	u12 bottom
70	u12 top
71	u13 bottom
72	u13 top

MODEL CPU BOARD THERMOCOUPLES (TC)

TC	COMPONENT/LOCATION
41	u3 bottom
42	u3 top
43	board bottom vicinity u30 and u35
44	board bottom vicinity u10 and u17
45	inside wall of j2 (case)
46	inside wall of j1 (case)
47	board top vicinity u10 and u17
48	board top vicinity u20 and u26
49	board top vicinity u30 and u35
50	board top vicinity u27 and u32
51	air vicinity u30 and u28
52	air vicinity u2 and u11

Table 4

ULM I/O BOARD THERMOCOUPLES (TC)

TC	COMPONENT/LOCATION
53	ul bottom
54	ul top
55	ull bottom
56	ull top
57	ul3 bottom eprom
58	ul3 top eprom
59	ul3 bottom
60	ul3 top

ULM CPU BOARD THERMOCOUPLES (TC)

TC	COMPONENT/LOCATION
73	u3 bottom
74	u3 top
75	air vicinity u30
76	air vicinity u38

Table 5

COMMON THERMOCOUPLES (TC)

TC	COMPONENT/LOCATION
45	J2 inside (case)
46	J1 inside (case)
53	ambient air for model runs after 13 AUG 1983--see note
72	ambient air for ULM on 12 AUG 1983--see note
77	ambient air for all runs prior to 13 AUG 1983--see note
77	backpack air for all runs from 12 AUG 1982--see note
78	inside front wall of case
79	J2 outside (case)
80	J1 outside (case)

NOTE: Changes to thermocouple locations were required on 12 AUG 1983.

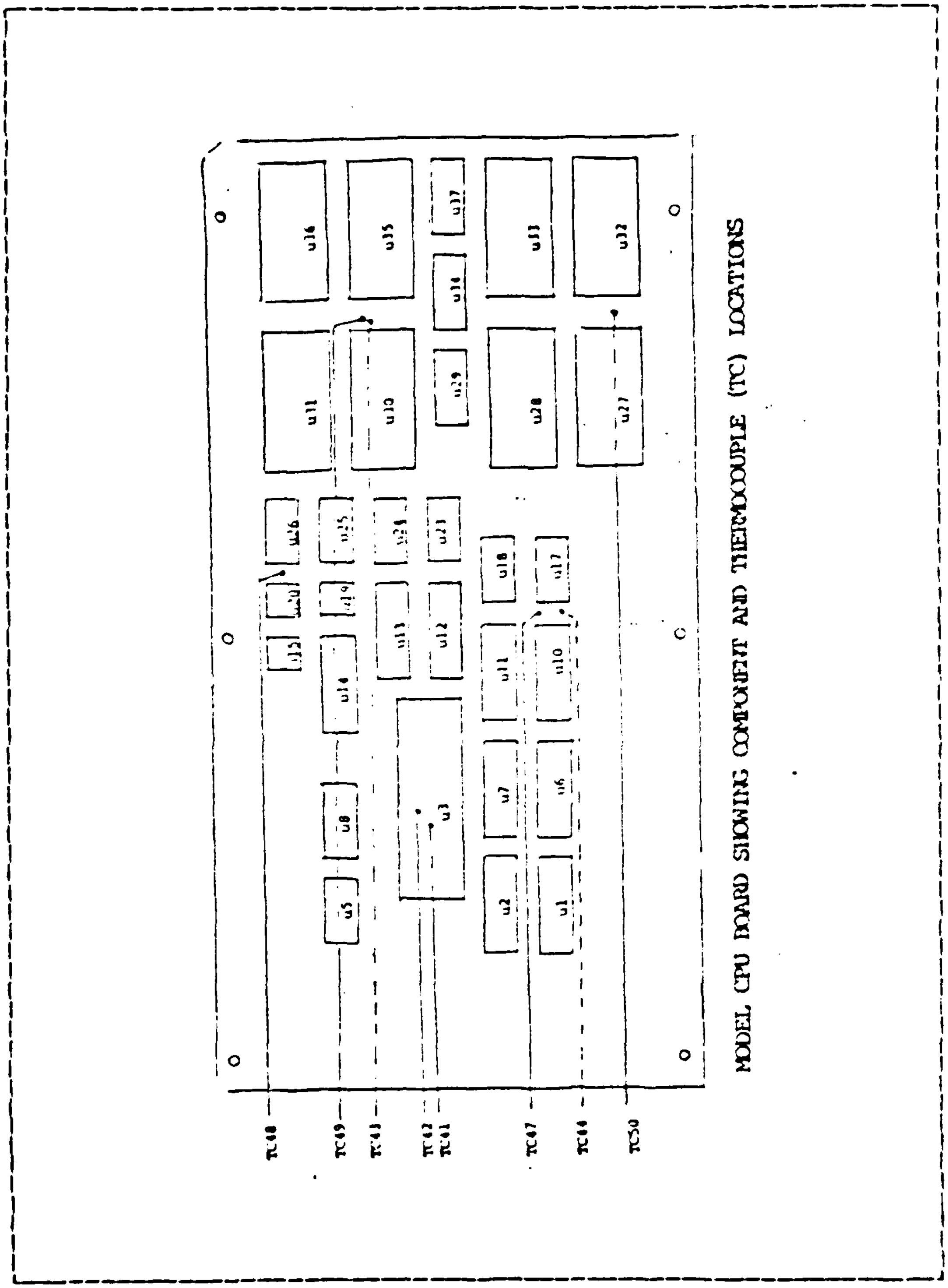

Figure 2.1 MODEL CPU BOARD.

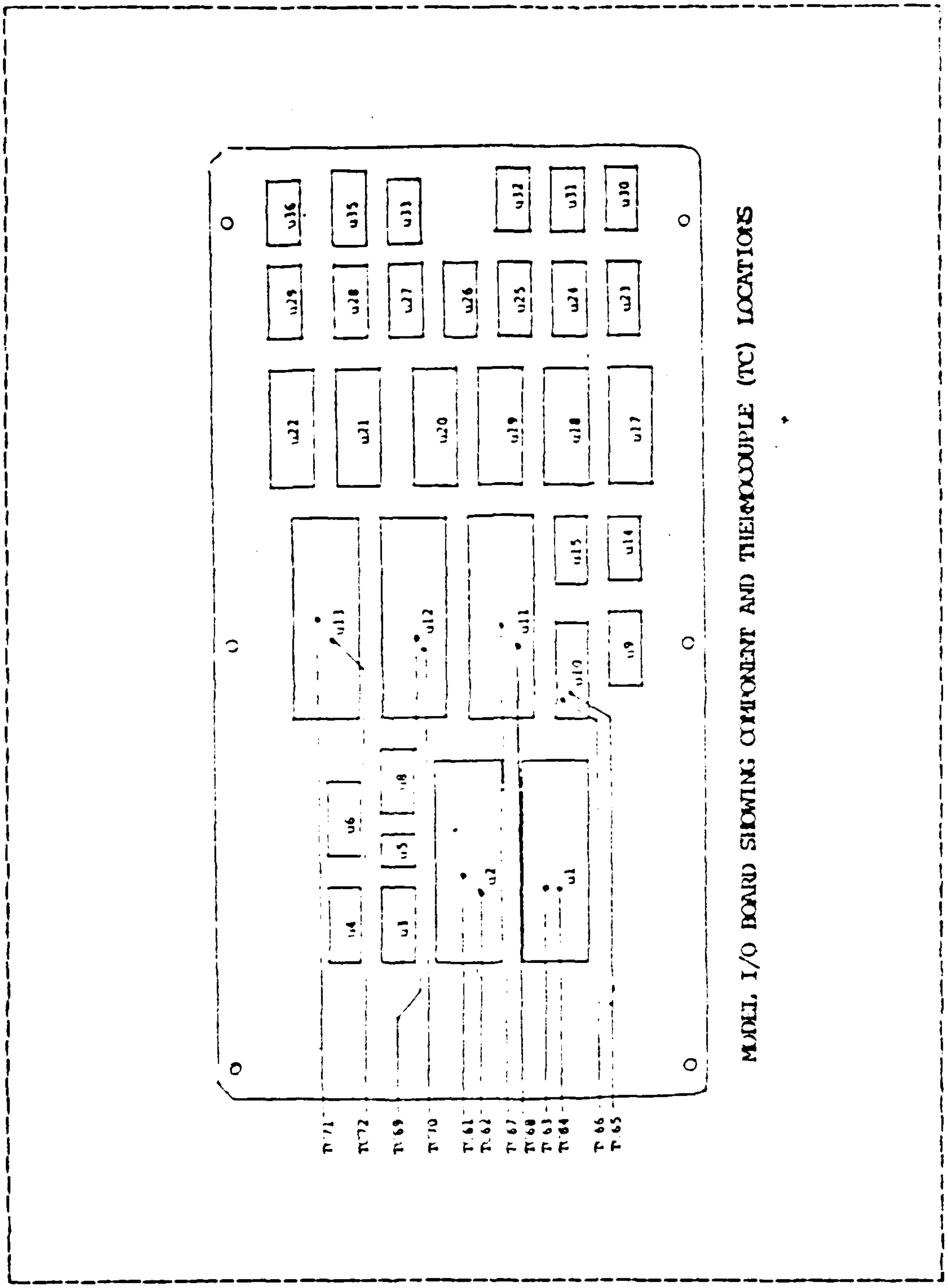

Figure 2.2 MODEL I/O BOARD.

wires individually. The unit was made almost air tight by packing the hole with silicon rubber sealant.

Power to the ULM was provided by a Lambda 60 volt power supply capable of voltage and current limitation. A Dana Digital Multimeter Model 4200 was used to monitor and adjust the power to the ULM/model, and check resistances. For gathering data, the HP3054 Data Acquisition System was utilized. It consisted of the HP3456 Digital Voltmeter for reading compensated EMF values from the thermocouples and the HP3497 Data Acquisition Control unit for controlling data flow. An HP 9826 computer was used to control the HP3054 and to store data on 5.25 in. floppy disks (see Appendix A).

The system was set up as follows:

- A calibrated 2 ohm resistor was put in series with the load (model/ULM) to obtain accurate current measurements for calculating input power.
- A junction board containing a switch for reading the voltages of the resistor and the load was fabricated.
- The schematic is shown in Figure 2.3.
- Power to the unit was controlled by the settings on the Lambda power supply.
- Temperature was measured by using the thermocouples, the HP3054 system, and the HP9826 computer. The schematic is shown in Figure 2.4.

The actual ULM circuit boards and a backpack became available for testing at this point. It was then decided that the actual ULM would be instrumented similarly to the

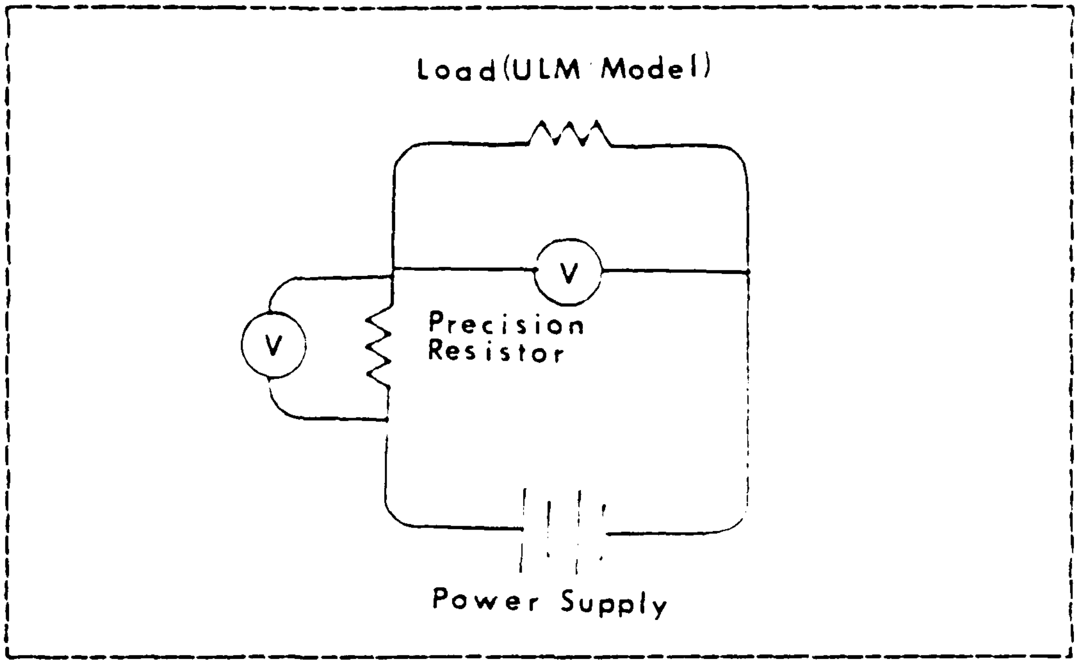

Figure 2.3 SCHEMATIC OF POWER SETUP.

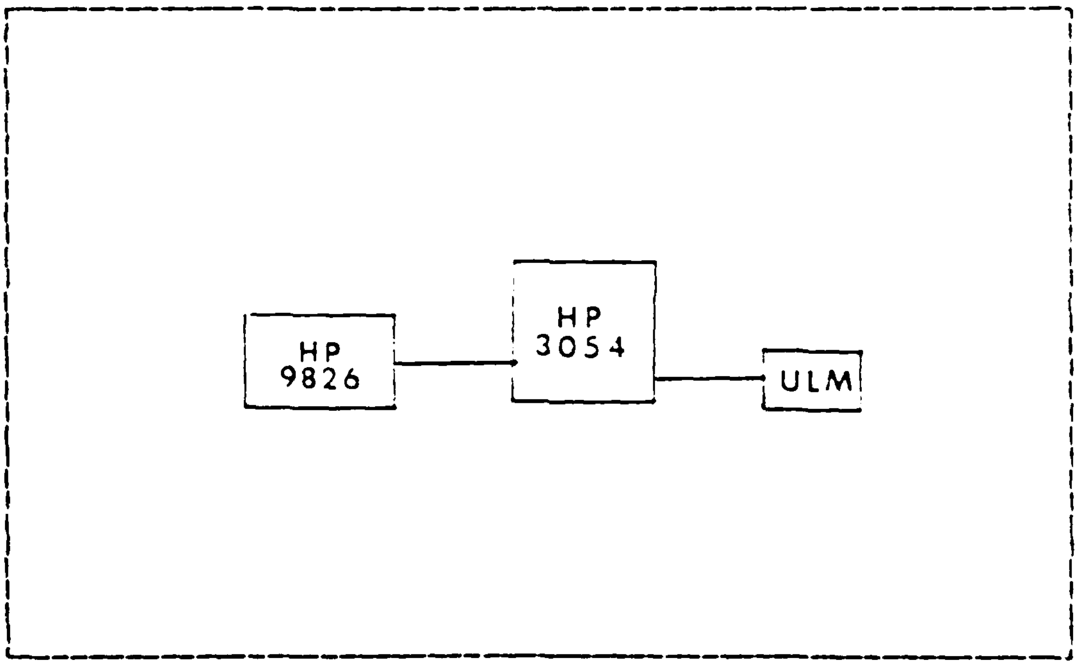

Figure 2.4 SCHEMATIC OF DATA ACQUISITION SETUP.

model. Unfortunately, the ULM could operate only in its typical operating range, and therefore could not be tested under max power ratings. An environmental chamber with variable temperature control was available for use. The environmental chamber had a maximum limit of 48.8C on its control system and was the size of a small room-- approximately 40 square feet. This allowed the backpack and ULM to be placed within the chamber in a stabilized environment while being monitored and controlled from outside the chamber. The test procedure was implemented as follows:

- The ULM and model would be run under room temperature conditions to test for proper operation of the systems and to ascertain the operating characteristics of each.
- The ULM would then be installed in the environmental chamber to determine the ambient temperature at which critical temperatures would be reached.
- The ULM and data acquisition system were then transported to Ft. Hunter Liggett on a typical summer day for testing in the ULM's actual environment.
- The model then replaced the ULM in the backpack and tests were again conducted in the environmental chamber. This time runs were conducted in an attempt to exactly simulate power and environmental conditions of all the ULM tests.

B. CONDUCT OF TESTS

This section will cover the specific procedures of all runs performed in the analysis. Data from the runs are contained in Appendices D through G. 40 thermocouples were assembled and divided between the ULM boards, model boards, the case, and external locations, which are listed in Table 3. Programs were written to automate the data acquisition process. All programs were in Hewlett Packard Basic 2.0 programming language. Specific programs were written for:

- Data acquisition and storage during the calibration procedures. These are contained in Appendix B.
- Calculation and storage of second order polynomial coefficients for calibration corrections of each thermocouple. This program is listed in Appendix B.
- Data acquisition and storage of temperatures for each thermocouple of the model. This program is in Appendix C.
- Data acquisition and storage of temperatures for the ULM thermocouples. This program is listed in Appendix C.

The data acquisition programs for the model and the ULM were interactive and required the following input:

- Month, day, hour, minute and second of the start of the run. This was required to set the internal clock of the HP 3497 control device.
- Voltage readings for the load and the calibrated resistor for calculation of the power and current values.
- The time interval for the wait between data sets.
- Number of data sets to be taken automatically.

The ULM model was first tested on 16 July 1983 in Halligan Hall, room 103. Using the setup previously explained, the model was placed on its side on a wooden board. The ambient temperature of the room was 24C (73F). The purpose of the test was to:

- Check the operation of the model and the system.
- Obtain data for further planning of test procedures.

After studying initial data, it was obvious some of the heaters were not operational. The overall resistance of the system was approximately 3.1 ohms and was checked before and after the tests. However, when power was applied, some of the solder connections were non-conducting electrically. This required resoldering and reassembly of the model boards. The next test for the model was conducted on 18 July 1983 in the same location and under the same conditions as the first test. Power was set at 10.71 watts, and 10 runs were taken at 60 minute intervals. Power was increased to 15 watts--the maximum power level predicted by CDEC for their critical maximum temperature of 85 C. Therefore, to prevent damage to the components, this test was terminated. An examination of this initial data taken at room temperature indicated that if the ULM and the model were to react similarly, the ULM would have problems operating in extreme conditions.

On 26 July the first ULM test was conducted for the same purpose as the first test on the model. However, this test was conducted with the ULM instrumented and placed inside the backpack. The pack was placed in a horizontal position in the same location and under the same conditions as the model test. 10 readings were taken at 5 minute intervals to obtain transient temperature data. Power was set at 8.72 watts. Next, 8 readings were taken at 30 minute intervals to obtain steady state data. The settings resulted in a power level of 8.71 watts. Since power could not be incremented to maximum on the ULM, lower temperatures--as compared to the model--were obtained on the ULM.

It was noticed there was a danger of cutting the thermocouple wires when inserting and extracting the module to and from the backpack. Therefore it was decided to complete all tests on the ULM before conducting tests on the model. The environmental chamber was then modified to accept the cabling for control of the power and thermocouples. It was heated to 48.8C (120F), the maximum setting for the chamber. For this temperature, it generally took 3 days to reach a constant internal temperature; therefore it was decided to start at this maximum setting. If this was too extreme for the ULM it would be faster to cool down the chamber than to heat it.

On 1 Aug 1983 the ULM was tested in the environmental chamber with the backpack in an upright position (this would be the usual position when carried by an instrumented soldier). 8 samples were taken in 5 minute intervals at a power level of 8.09 watts. 20 readings were then taken in 30 minute intervals with a power level of 7.59 watts at the same settings. The maximum temperature achieved was 78C (173F) on the CPU (u3). It was evident that none of the components would reach their critical temperatures under these conditions at typical power levels.

The ULM's next test was conducted at Ft. Hunter Liggett, Ca. on 12 Aug 1983. This was done to determine the effect that solar loading in the actual environment would have on the system. The backpack was placed in direct sunlight on a concrete pad in a vertical position. This test was started at 0800 hrs. and ended at 1500 hrs. on a typical summer day for that region. Ambient temperatures were taken from a location in the shade near the backpack. Some tests were initially taken to examine the sun's effect on internal pack temperatures. 10 samples were taken at 5 minute intervals with the ambient temperature ranging from 21.4C to 23.7C. Power was turned on, and 15 readings were taken at 5 minute intervals at a power level of 7.93 watts. The ambient temperature ranged from 24.1C to 29.1C. Next, 10 samples were taken at 15 minute intervals with power now at 7.56 watts. Ambient temperature for this run ranged from 30.3C to 34.5C. Due to the changing direction of the sun's rays, the backpack was reoriented to maintain full irradiation by the sun. This required moving the backpack off the concrete slab onto the dirt. 8 samples were then taken at 15 minute intervals with power at 7.44 watts with no change to the power settings. Ambient temperature ranged from 35.2C to 37.4C. Again none of the components reached its critical temperature. This completed testing of the ULM.

Returning to the Naval Postgraduate School, the model was placed in the backpack and tests were conducted in the environmental chamber to duplicate--for comparison--conditions of the ULM tests. On 14 Aug 1983 the model was tested with 8 samples taken at 5 minute intervals and a power level of 7.9 watts. Ambient temperature was at 43.3C for this run. Next, 20 samples were taken at 15 minute intervals at the same power level. On 15 Aug 1983 the temperature was set to 48.8C to duplicate the ULM's run on 1 Aug 1983. 8 samples were taken at 5 minute intervals at a power level of 7.91 watts. 20 samples were taken at 15 minute intervals, with power now at 7.97 watts. The final test run was taken--also on 15 Aug 1983--at 37.7C for obtaining data to compare steady state with and without solar loading at the same ambient temperature. 15 samples were taken at 5 minute intervals and power set at 7.72 watts. Next, 24 samples were taken at 30 minute intervals with power now at 6.62 watts.

III. EVALUATION OF RESULTS

A. RESULTS

Results are presented in this section with a summary of the observations of each test followed by the corresponding graphs produced from test data. The graphs depict the thermocouple temperatures plotted against time with either ambient or backpack temperatures, or both, shown for comparison purposes.

The test on 1 August 1983 was conducted at a constant temperature of 48.8C in the environmental chamber. The following are observations from data taken during these runs:

- None of the susceptible components reached its critical temperature of 85C.
- Max steady state temperatures achieved are shown in Figures 3.1 to 3.3 and are listed here as:

  u11 = 77.2C
  u3 = 78.6C
  u13 = 72.8C
  u1 = 61.1C

- Steady state was achieved at between 130 and 140 minutes after power was applied.
- Temperatures of internal and external portions of the case are:

  internal J1 (TC46) = 56.0C
  external J2 (TC80) = 54.4C

There were no unexpected trends or observations resulting from this test.

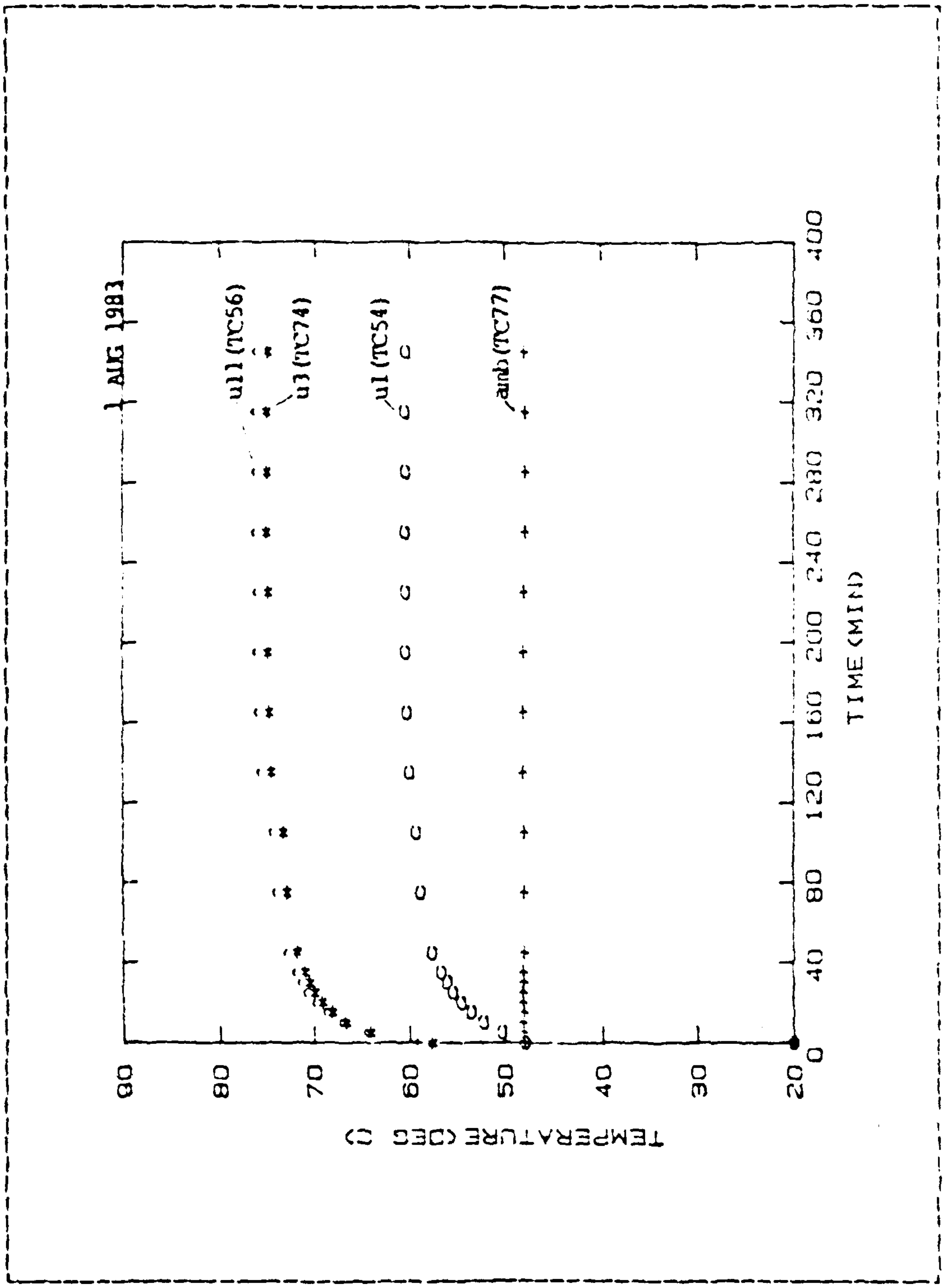

Figure 3.1   1 AUGUST 1983 - graph 1.

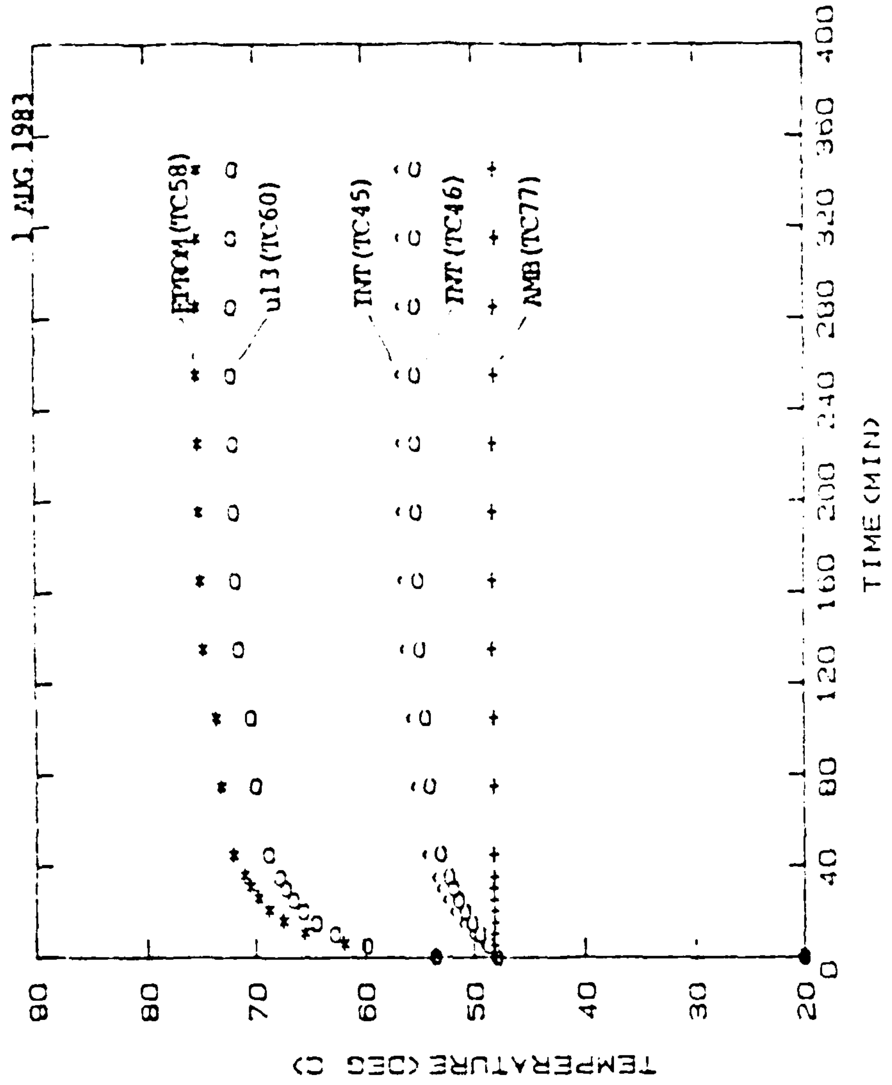

Figure 3.2 1 AUGUST 1983 _ graph 2.

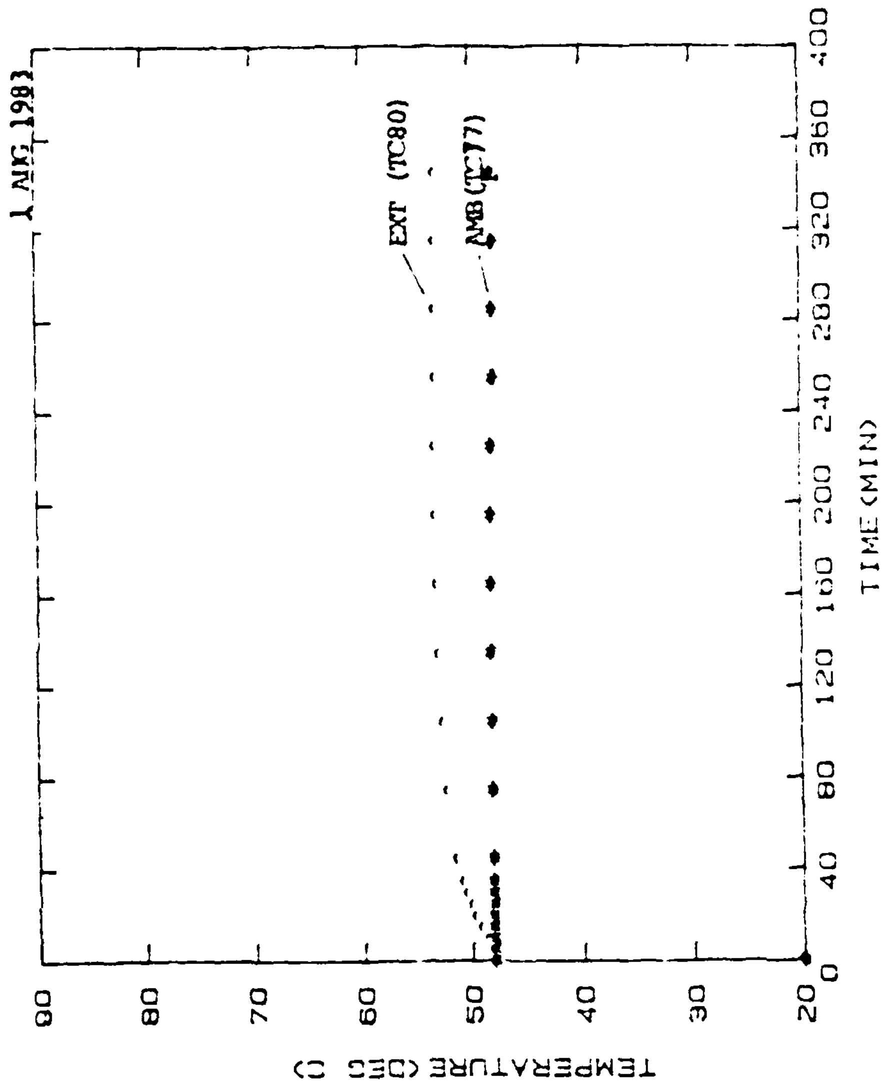

Figure 3.3   1 AUGUST 1983 - graph 3.

The test conducted at Ft. Hunter Liggett experienced ambient temperatures ranging from 21C to 38C and fluctuated due to occasional wind currents. This test began at 0800 hrs. on 12 August 1983, and terminated at 1530 hrs. on the same day. The following was observed:

- None of the susceptible components reached its critical temperature of 85C.

- Max steady state temperatures acheived are shown in Figures 3.4 to 3.8 and are listed here as:

  u11 = 78.78C
  u3 = 79.16C
  u13 = 78.4C
  u1 = 64.3C

- The internal pack temperature reached a maximum of 60.8C--22.8C above ambient--as a result of solar loading and internal heat produced by the ULM.

- Although steady state was not reached (due to ambient temperature fluctuations), the effects of transient heating appears to have taken between 130 to 140 minutes. This is due to the heating by the components as opposed to external solar loading.

- Apparently, moving of the pack disturbed the external thermocouple (TC80) causing it to give spurious readings after 250 minutes as seen in Figure 3.5. This is most likely a result of loose connections at the thermocouple connectors.

- The sudden jump in temperature at 30 minutes (for TC's 54, 56, 58, 60 and 74) is a result of the power switch being turned on. Temperature increases prior to 30 minutes are due only to the effect of solar radiation on the backpack.

The first 15 August 1983 test on the model was conducted in the environmental chamber at an ambient temperature of 48.8C. Observations resulting from this test are:

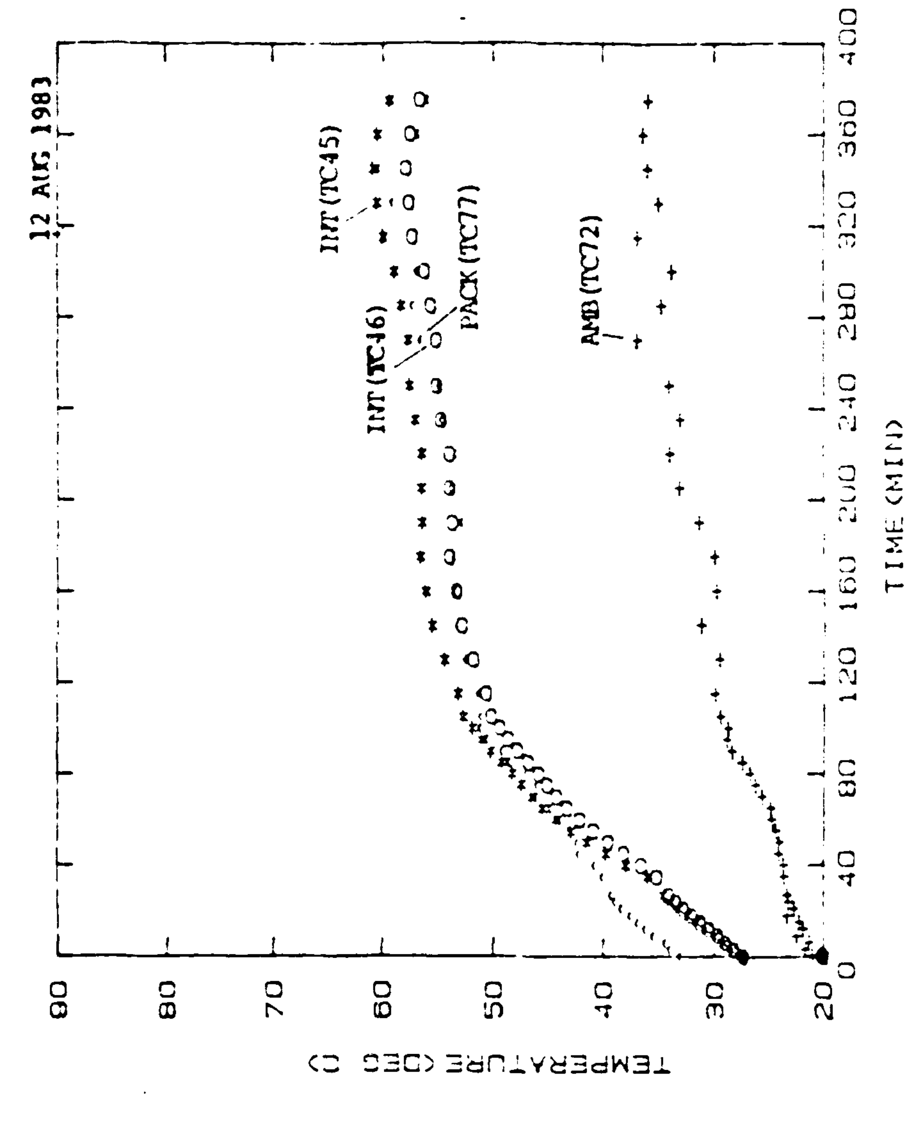

Figure 3.4 12 AUGUST 1983 - graph 1.

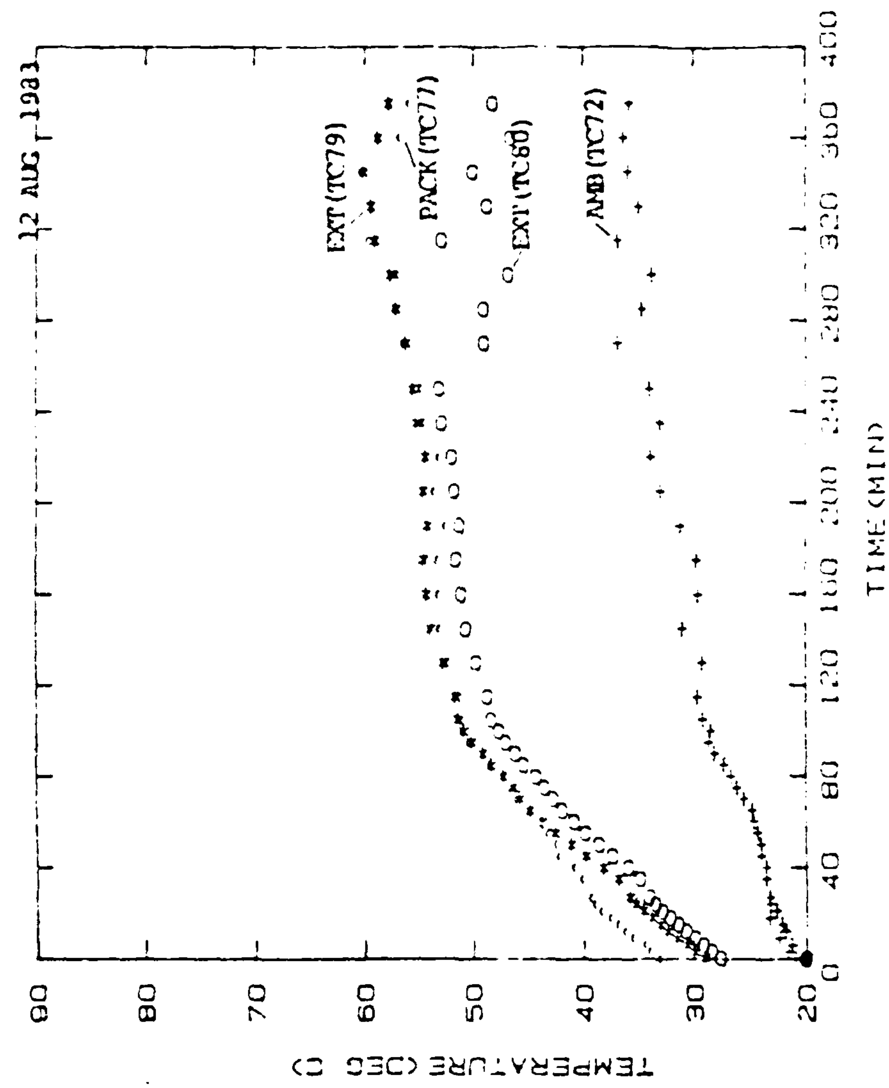

Figure 3.5   12 AUGUST 1983 _ graph 2.

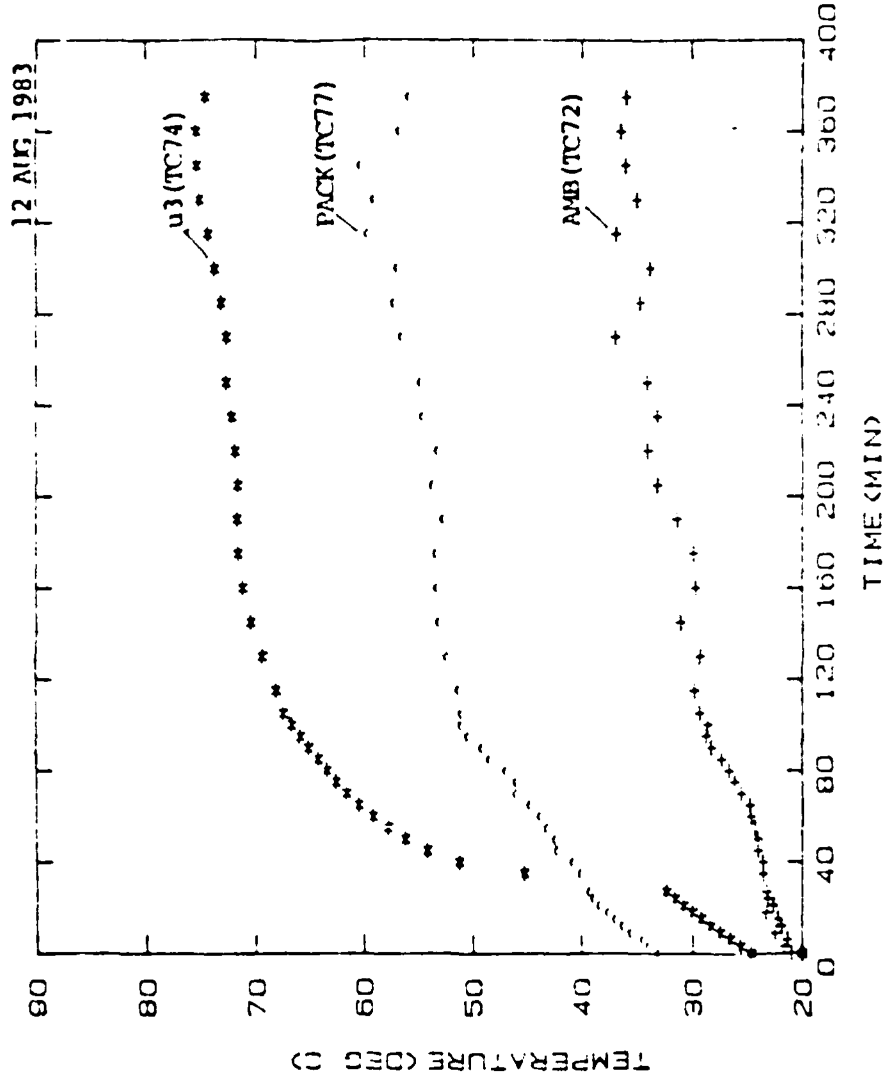

Figure 3.6   12 AUGUST 1983 - graph 3.

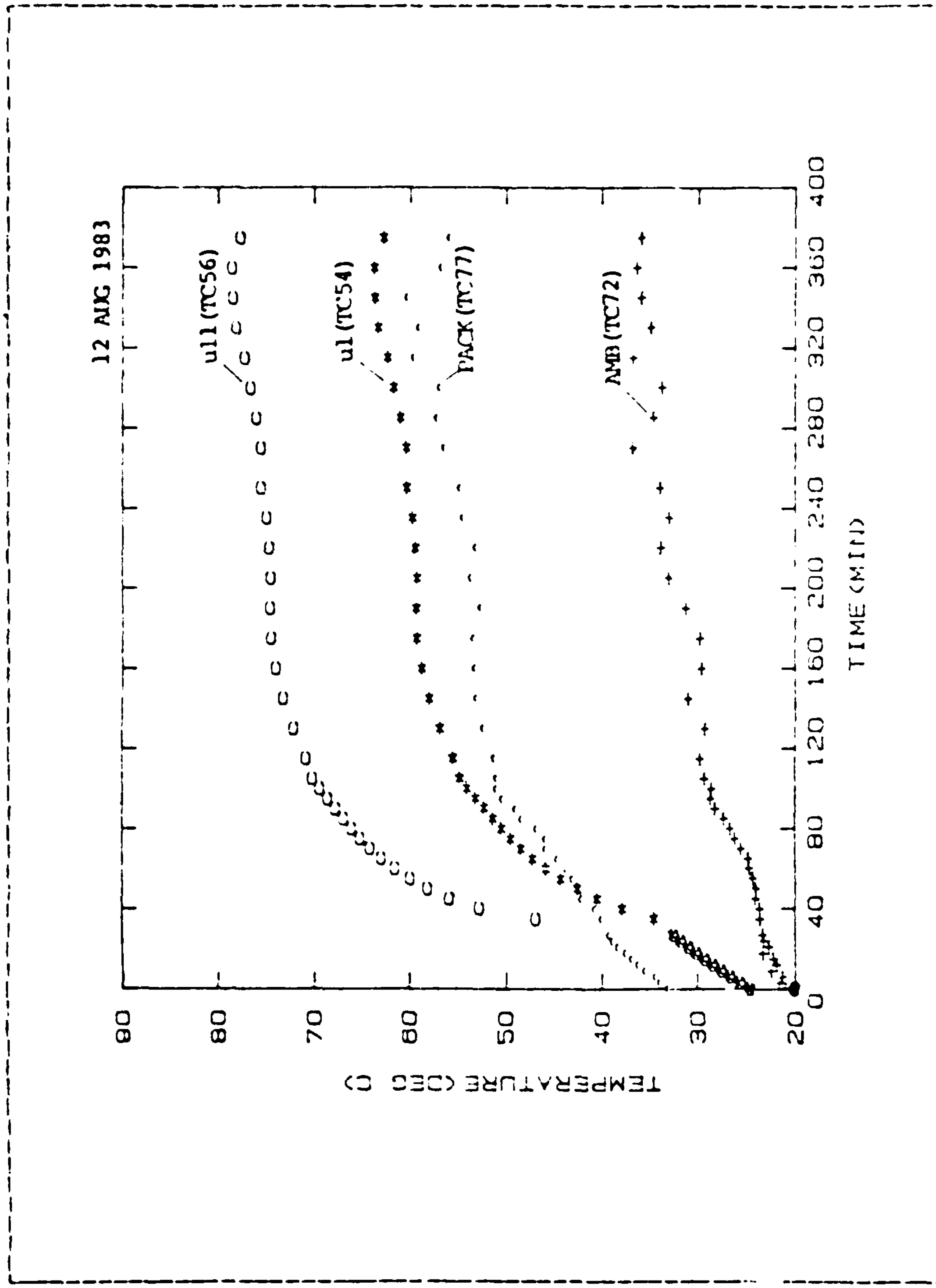

Figure 3.7   12 AUGUST 1983 _ graph 4.

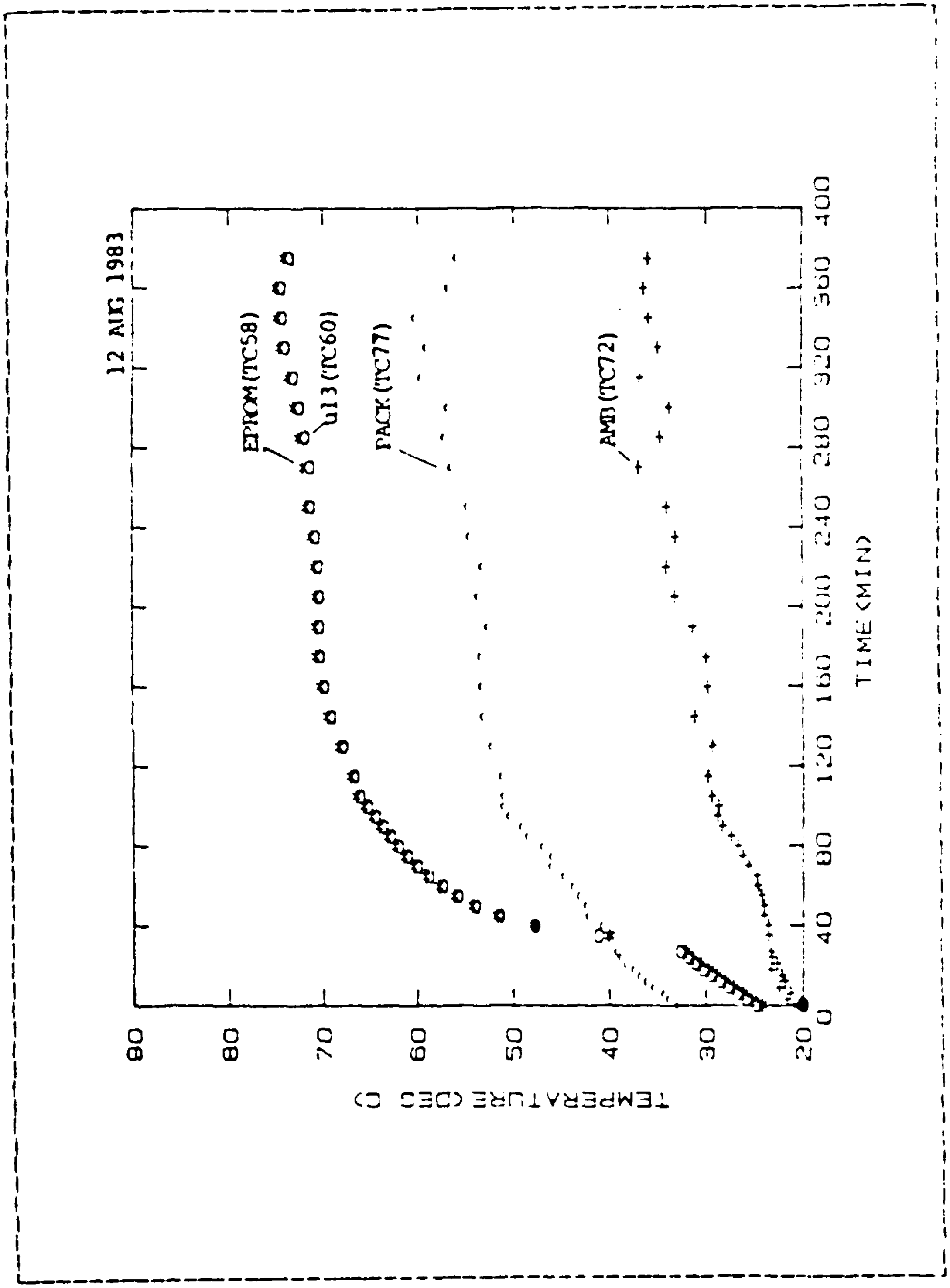

Figure 3.8 12 AUGUST 1983 - graph 5.

- None of the susceptible components reached its critical temperature of 85C.

- Max steady state temperatures achieved are shown in Figures 3.9 to 3.11 and are listed here as:

  u11 = 76.11C
  u3 = 66.80C
  u13 = 77.54C
  u1 = 84.58C

- As a result of internal heat produced by the ULM, the internal pack temperature reached a maximum of 54.8C--6C above ambient.

- Unexpected temperature fluctuations occurred at 45, 120, and 300 minutes on TC's 42, 64, 68 and 72. Since the only thermocouples experiencing these fluctuations were attached to powered components, this may have been caused by a power fluctuation of the power supply.

The second test of the model on 15 August 1983 was conducted again in the environmental chamber set this time to an ambient temperature of 37.7C. Observations from this test are:

- None of the susceptible components reached its critical temperature of 85C.

- Max steady state temperatures achieved are shown in Figures 3.12 to 3.14 and are listed here as:

  u11 = 60.22C
  u3 = 52.33C
  u13 = 63.60C
  u1 = 68.78C

- As a result of internal heat produced by the model, the internal pack temperature reached a maximum of 41.1C.

- Steady state was achieved between 80 and 120 minutes after power was applied.

- Unexpected temperature fluctuations occurred in TC's 53 and 68, between 5 and 15 minutes. These fluctuations cannot be explained.

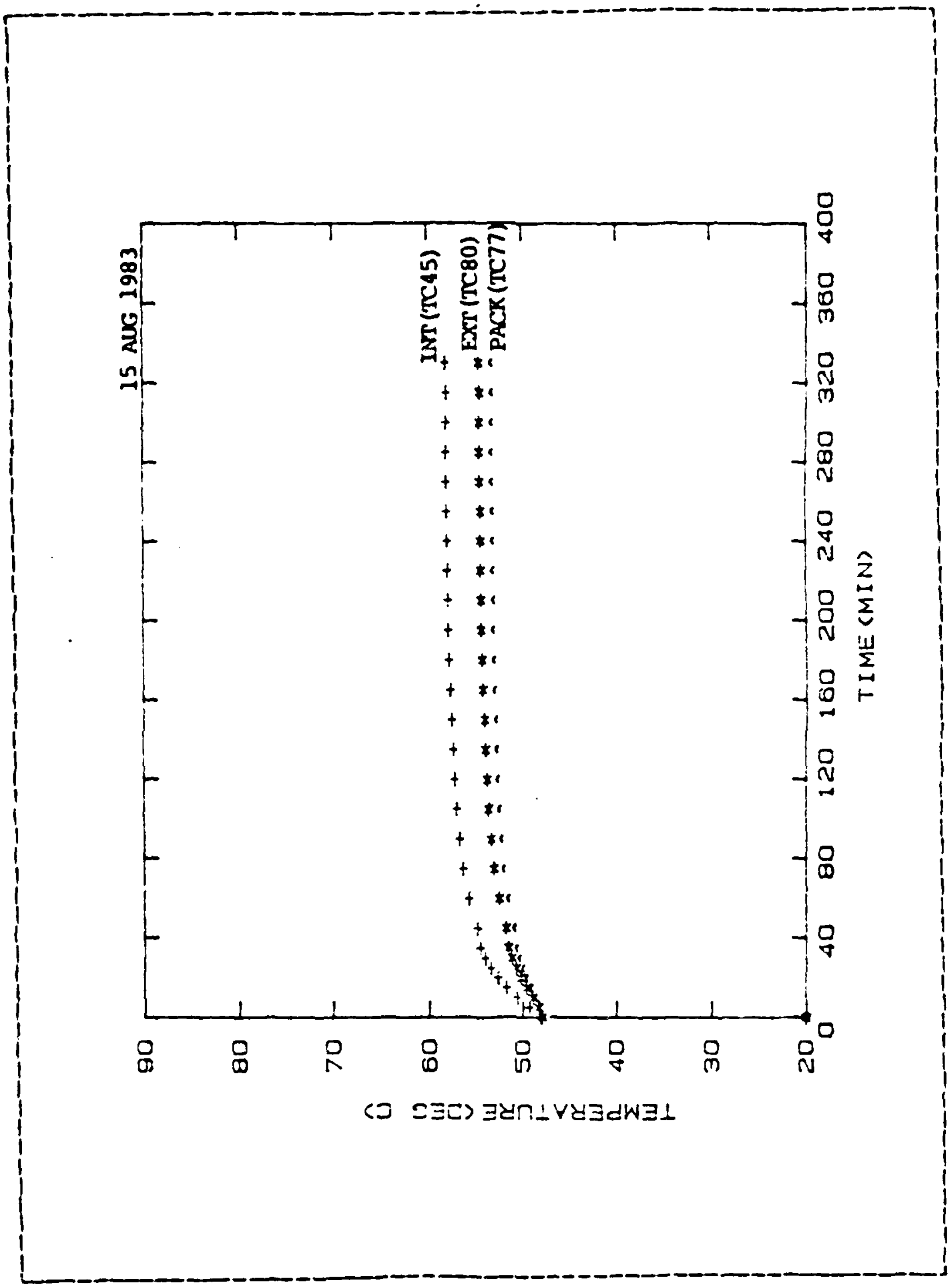

Figure 3.9 15 AUGUST 1983 (AMBIENT = 48.8C) - graph 1.

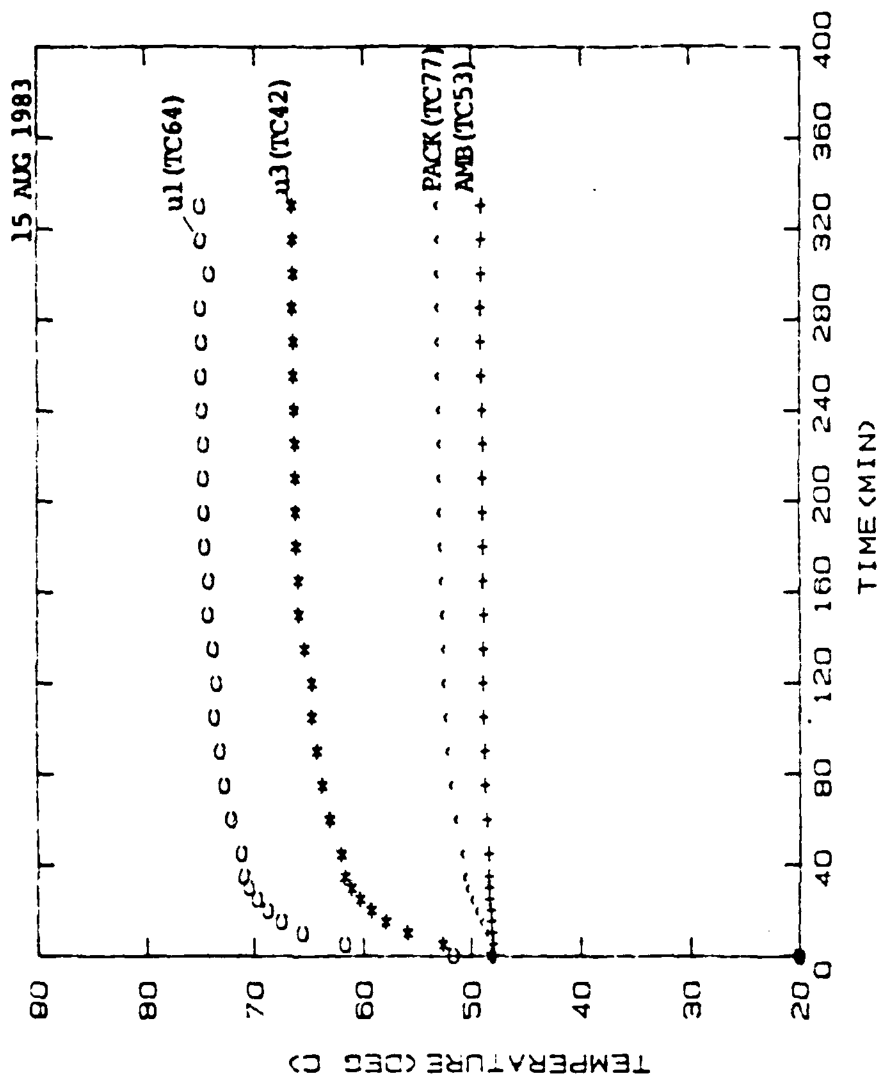

Figure 3.10 15 AUGUST 1983 (AMBIENT = 48.8C) - graph 2.

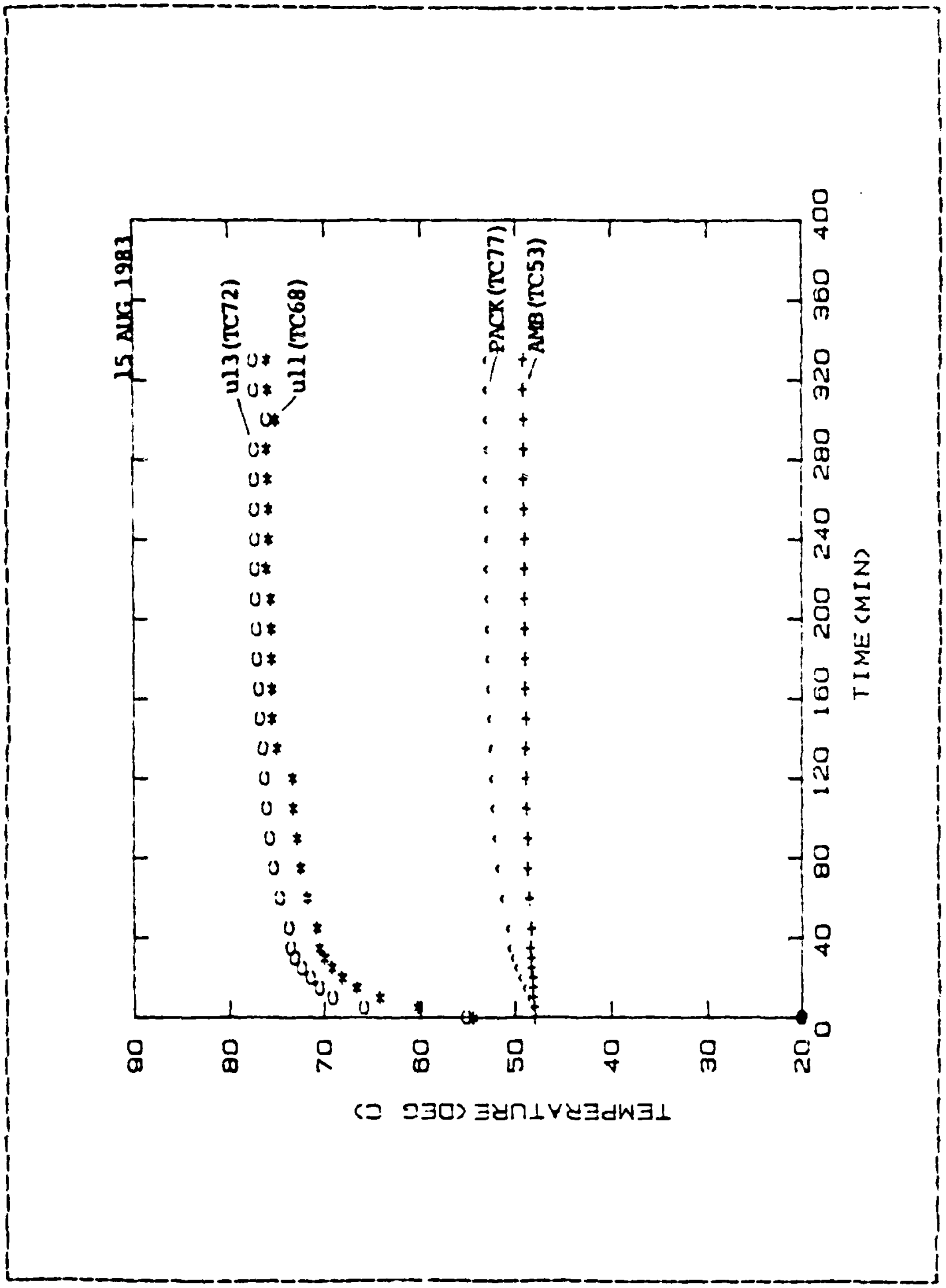

Figure 3.11 15 AUGUST 1983 (AMBIENT = 48.8C) - graph 3.

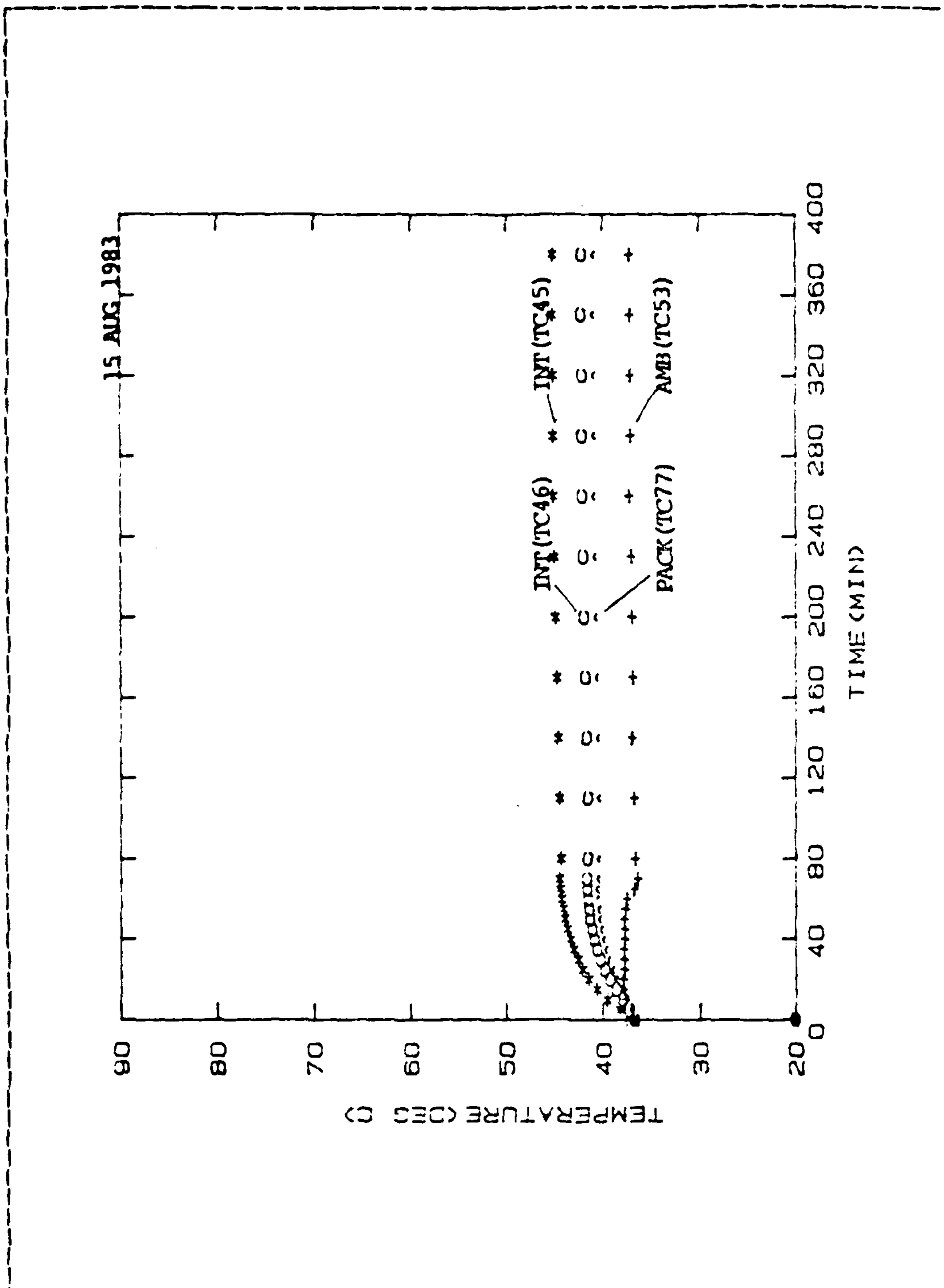

Figure 3.12 15 AUGUST 1983 (AMBIENT = 37.7C) - graph 1.

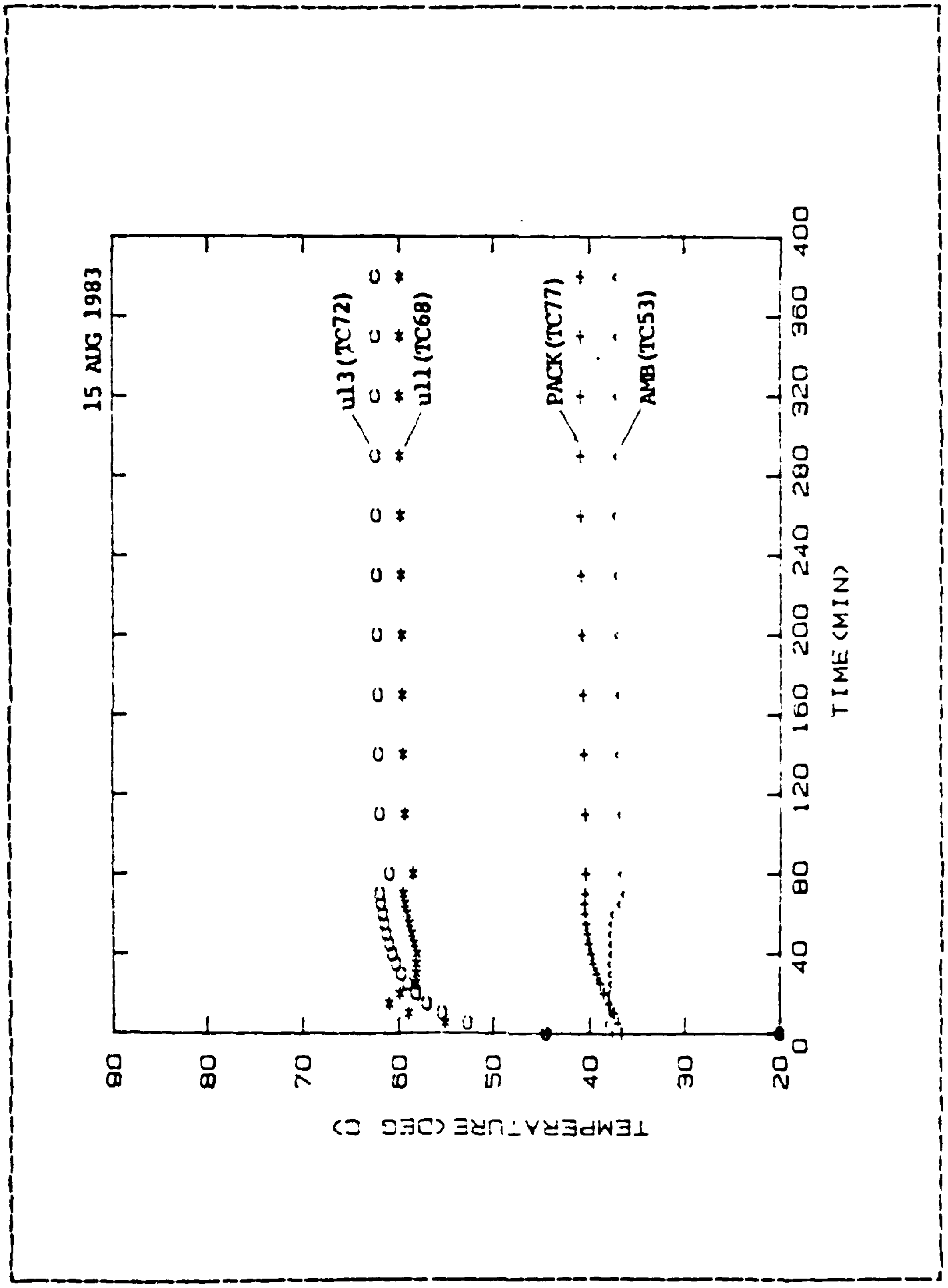

Figure 3.13 15 AUGUST 1983 (AMBIENT = 37.7C) - graph 2.

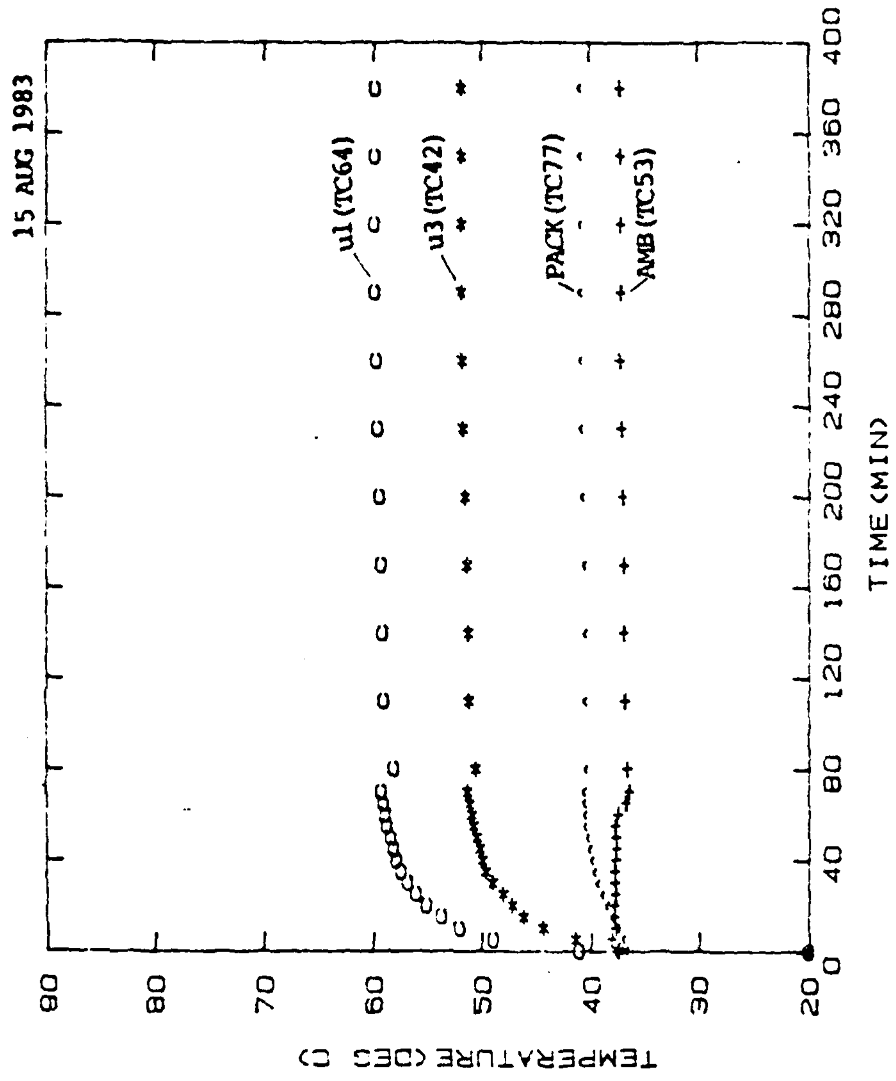

Figure 3.14 15 AUGUST 1983 (AMBIENT = 37.7C) - graph 3.

- Unexpected temperature fluctuations occurred in all thermocouples between 50 and 80 minutes. It appears that all the fluctuations lag slightly behind that of the ambient air fluctuation. An actual change in ambient air temperature would have this type of delayed response. Since the environmental chamber was not monitored continuously, the door may have inadvertently been opened, or there may have been a short loss of power to the heating system of the chamber.

B. DISCUSSION

The ULM and backpack will be subjected to ambient environments ranging typically from 21C to 38C during the warm summer season. Solar loading--typical of a Ft. Hunter Liggett summer day--could add 22C higher environmental temperatures within the backpack resulting in a higher stress experienced by the ULM.

Energy in the form of heat will naturally flow from a hot element to a colder one. The rate of heat flow (Q) is proportional to the temperature difference (ΔT) and inversely proportional to the thermal resistance ($\underline{\theta}$) of the medium through which the heat is flowing. This relationship is:

$$Q = (\Delta T)/\underline{\theta}$$

In the ULM--as in most electronic equipment--most of the energy used to power the equipment is converted to heat, causing the equipment temperature to rise. The temperature will continue to rise unless the heat can be removed. In the ULM, the power input to the module is the total energy that must be dissipated. In the case of the ULM, the ultimate sink for thermal energy is the air outside the backpack. Both the air inside the backpack and the backpack itself, can be considered local sinks through which all energy leaving the ULM must flow [Ref. 4].

There are three modes of heat transfer at work in most systems:

- Conduction refers to heat transfer across a medium resulting from kinetic energy interchange between molecules or by electron drift [Ref. 5]. Conduction can occur in a solid, liquid, or gas and is the only mode of heat transfer occurring in an opaque solid [Ref. 4].

- Convection heat transfer occurs at the interface between a solid and a fluid at a different temperature when fluid motion is present. The fluid of this analysis is air. Motion caused by the density differences associated with the temperature variation within the fluid is called natural convection. Motion caused by external methods is forced convection. In this analysis the only forced convection is when wind is present [Ref. 5].

- Radiation heat transfer refers to the energy emitted by matter in the form of electromagnetic waves. Given two surfaces at different temperatures, each will be emitting and exchanging thermal radiation. However, the net radiation exchange is in the direction of hot to cold and will continue until both surfaces are the same temperature. At this point the net radiation will be zero [Ref. 6]. The net radiation occurring between two bodies with similar surface material, is a function of the intensity which varies with the viewing direction between the emitting surfaces. Thus the energy transferred from one surface to another is a function of the area of the receiving surface "seen" by the emitting surface [Ref. 5].

The primary heat flow paths of this system are:

- From each component to the ULM case via convection and conduction.

- From ULM case to backpack by convection through the air, by conduction through the backpack frame, and by radiation.

- From backpack to ambient air via forced and natural convection, and radiation.

Because of the geometric positioning of the components, radiation was not considered as playing a very significant role in the component to ULM case heat flow path. The dissipating elements are flat DIP devices whose sides make up a small proportion of emitting surface. The greatest surface area is the top of each component. When assembled, each of these surfaces is facing another dissipating surface. This would have an effect of heating the lower temperature device, but as both are power dissipators, the net effect in terms of energy dissipation would be negligible.

Natural convection and conduction would be the primary heat transfer modes of energy transfer from the component to the air. Since the ULM was hermetically sealed, the only fluid motion would be caused by natural convection. The dense packing of the components leaves little room for temperature gradients to occur between components on the same board. The space between the boards and the top surfaces of the components vary with the component. Some components would act as barriers to air flow resulting from adjacent components. Unfortunately, all high power dissipating components are clustered at one end of the ULM.

Additionally, the hot components of the I/O board directly face the hot components of the CPU board. Since the air is being heated from two directions, the cooling effect of the air on the surface of each component is reduced. Thus, due to the geometric configuration and high concentration of high power dissipators, it is postulated that much of the advantage in cooling achieved by natural convection is offset by the dual heating effect. This would leave conduction as the dominant heat transfer mode within the ULM.

Conduction within the ULM will occur from component to air to the case, and component to board to the case. Since the boards are separated from the case by electrically insulating gaskets, most of the conduction will take place from boards and components to the air--then to the case. With the available data, however, it is impossible to quantify how much heat is conducted by the boards to the case compared to conduction from the components to the case.

Ideally all thermal paths with their individual resistances would be calculated. However, the complexity of this device and amount of instrumentation required for this type of analysis made such a task impractical. It would have required calculating not only the path of the energy from each component to the ultimate sink, but also the effect each of the other components would have at each temperature along the path. Even if the device could be instrumented to determine all of these temperatures, the individual power dissipating rates for each component of the actual ULM would have to be available. This data was not available. Unfortunately there is little correlation between the behavior and resistances of IC components and the resistors used to model the components. This is because power dissipation in the IC components is frequency dependent and not based solely on voltage supplied to and the resistance of the component. This is the case for the model, which is made of resistors having a fixed value. Thus little correlation existed between the actual component and its model, in terms of individual power dissipation. Knowing the total dissipation of the ULM enabled calculating an equivalent thermal resistance from the internal backpack air to the ambient air shown in Figure 3.15. These calculations are based on the following assumptions:

- The temperature measured inside the backpack is assumed to be representative of the average value of the air within the backpack.
- Heat dissipated by the backpack frame directly to the ambient air is assumed to be negligible compared to the heat dissipated by the internal backpack air through the canvas to the ambient air.

Using data from the environmental chamber on 13, 14, 15 August, 1983, and the relation:

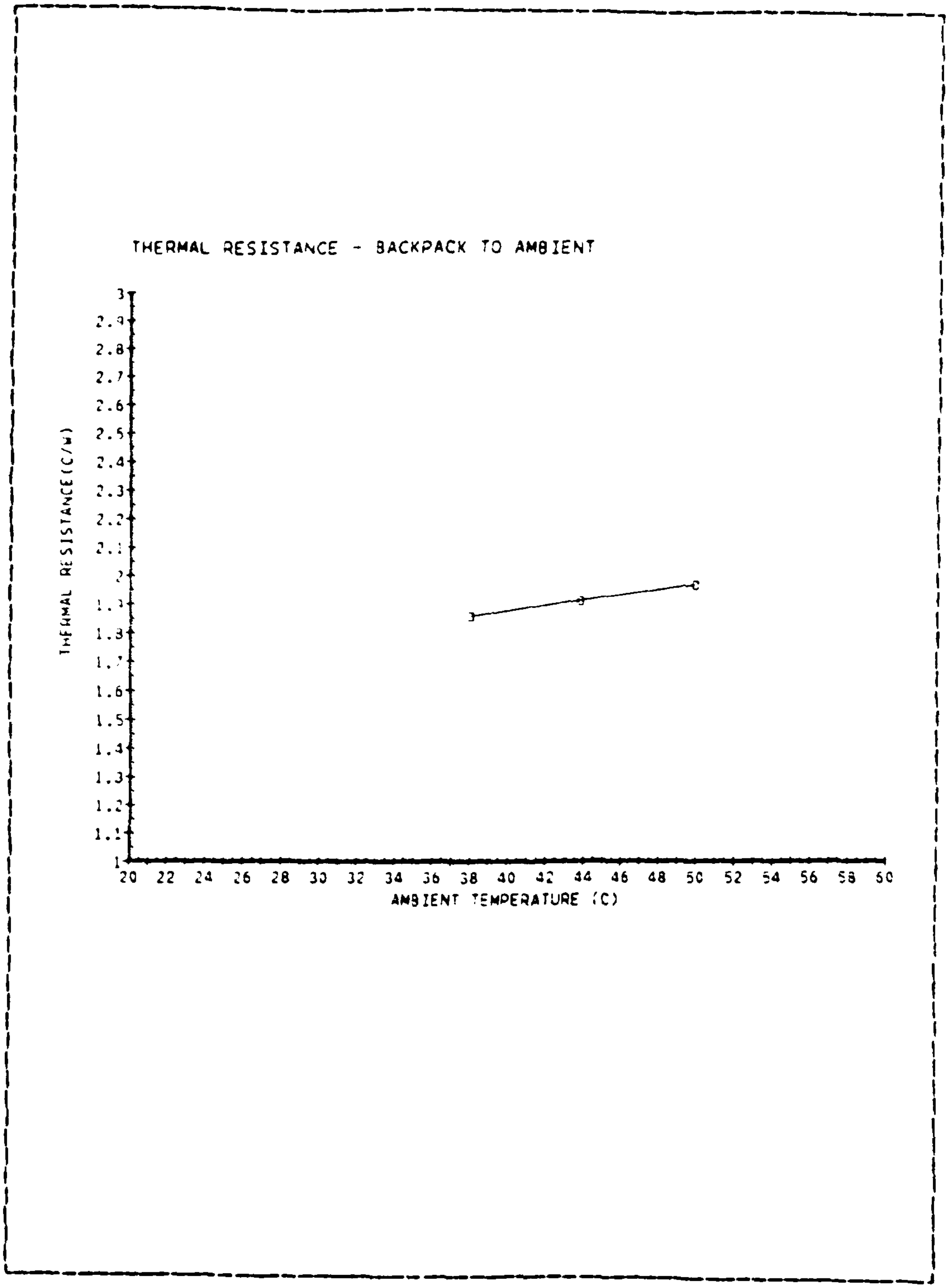

Figure 3.15 THERMAL RESISTANCE OF PACK AIR TO AMBIENT.

$$Q = \theta / \Delta T$$

Theta was calculated as 1.86 C/W for the test of 12 Aug 83. Therefore, since the total heat within the pack was the sum of the ULM load and the solar load, the solar load was calculated as 29.67 watts. This is as if in the absence of solar loading, the ULM--at 8 watts--was joined in the backpack by an additional unit of 30 watts. This is a very significant additional thermal stress

C. CONCLUSION

Operating under typical power consumption rates (approximately 8 watts) under design environmental conditions of Ft. Hunter Liggett in the summer, all internal components were measured to be below their specified critical temperatures of 85C or higher. The design conditions meant here are:

- An environmental temperature range of 21C to 38C (70F to 100F)
- The ULM mounted in a backpack
- No additional internal heat sources
- The backpack in direct sunlight
- No wind.

However, operating under these conditions causes several of the components, whose critical temperatures are 85C, to be within 5 to 10C of that limit. Therefore, any slight increase in power over 8 watts, or increase in ambient

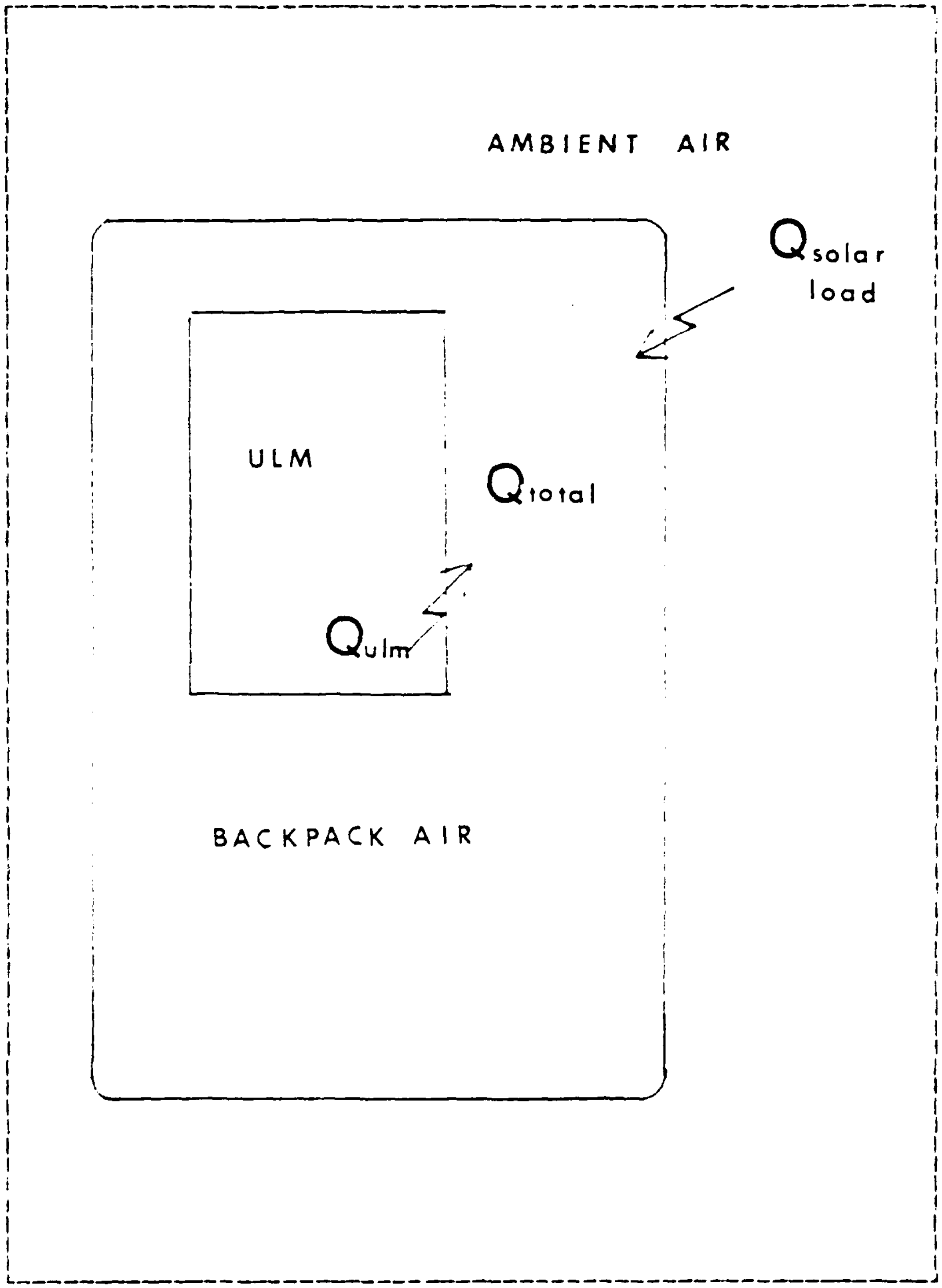

Figure 3.16 ENERGY BALANCE ON THE BACKPACK.

temperature above 38C, could cause one or more of the components to exceed specifications. Then reliability of the system could not be predicted, and would be substantially decreased. Conversely, the absence of direct sunlight and/or the addition of wind would have a beneficial effect on the ULM by decreasing the thermal stress on the unit.

APPENDIX A

EQUIPMENT LIST

The following is a list of the equipment used for this analysis:

- Thermocouples were made of copper-constantan, 30 gauge, teflon coated thermocouple wire.
- The HP3054A Automated Data Acquisition System was used for data acquisition which consists of:

  HP3497 Data Acquisition Control Unit

  HP3456 Digital Voltmeter for obtaining data from the thermocouples
- The HP9826 Desktop computer was used to control data acquisition, storage of data, computation and display of data.
- The Lambda 60 volt power supply was used to provide power to the ULM and model.
- A Controlled Acoustic Environmental Chamber manufactured by Industrial Acoustics Company Inc. was used for simulating ambient temperatures up to 48.8C (120F).

APPENDIX B

THERMOCOUPLE CALIBRATION

The following is a list of equipment used during the calibration of the thermocouples:

- Rosemount Engineering Model 920a Commutating Bridge
- Rosemount Model 162 Platinum Resistance Temperature Standard
- HP3054 Data Acquisition System
- HP9826 Desktop Computer

A computer program listed on page 62 was written for the HP9826 to:

- Read emf values from the thermocouples
- Store the emf values in a data file
- Convert the emf values to temperatures based on a reference relative to platinum at 0C.
- Compare these temperatures to temperatures obtained from the platinum resistance standard.

A second program was written to fit a second degree polynomial to the comparison above and for obtaining coefficients to apply to each thermocouple. This program is listed on page 63.

The thermocouples and the platinum resistance standard were placed in the calibration bath. The temperature of the bath was cycled from 10C to 100C and back to 10C. Temperature measurements were taken at 20 degree increments ascending and descending the scale. Coefficients correcting the thermocouple temperatures to the standard temperatures were calculated and listed on pages 64-67.

```
100! FILE NAME: CAL
110! REVISED:   May 20, 1987
120  COM /C/ C(7)
130  DIM Emf(39),T(39),Delta(39)
140  DATA 0.10086091,25727.94369,-767345.8295,78025595.81
150  DATA -9247486589,6.97688E+11,-2.66192E+13,3.94078E+14
160  READ C(*)
170  PRINTER IS 701
180  BEEP
190  INPUT "ENTER MONTH, DATE AND TIME (MM:DD:HH:MM:SS)",Date$
200  OUTPUT 709:"TD";Date$
210  OUTPUT 709:"TD"
220  ENTER 709:Date$
230  PRINT USING "12X,""Month, date and time: "",14A":Date$
240  BEEP
250  INPUT "GIVE A NAME FOR DATA FILE",D_file$
260  CREATE BDAT D_file$,30
270  ASSIGN @File TO D_file$
280  J=0
290 Repeat: !
300  J=J+1
310  BEEP
320  INPUT "ENTER BATH TEMPERATURE (DEG F)",T_bath
330  PRINT " "
340  PRINT USING "12X,""Data set number    = "",DD,":J
350  PRINT USING "12X,""bath temperature   = "",4D.DD,"" (Deg F)""":T_bath
360  OUTPUT 709:"AR AF40 AL79"
370  OUTPUT 722:"F1 R1 T1 Z1 FL1"
380  FOR I=0 TO 39
390  OUTPUT 709:"AS SA"
400  ENTER 722:Emf(I)
410  T(I)=FNTvsv(Emf(I))
411  Delta(I)=T_bath-T(I)
420  NEXT I
430  PRINT USING "(12X,5(5D.DD,2X),12X)":T(*)
431  PRINT " "
432  PRINT USING "12X,""DELTAS:""":
433  PRINT USING "(12X,5(5D.DD,2X),18X)":Delta(*)
440  OUTPUT @File:T_bath,T(*)
450  BEEP
460  INPUT "ARE YOU TAKING MORE DATA (1=YES,0=NO)?",Go_on
470  IF Go_on=1 THEN Repeat
480  BEEP
490  PRINT " "
500  PRINT USING "12X,DD,"" runs were stored in file "",10A":J,D_file$
510  END
520  DEF FNTvsv(V)
530  COM /C/ C(7)
540  T=0.
550  FOR I=0 TO 7
560  T=T+C(I)*V^I
570  NEXT I
580  RETURN T*1.8+32
590  FNEND
```

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```
1 !     FILE NAME:COEF_CAL
2 !REVISED:16 MAY 1985
3       DIM Em(39),T(39),Delta(39),Sx(39),Sy(39),Sx2(39),Sx3(39),Sx4(39),Sxy(39)
4       DIM Sx2y(39),Det(39),Det0(39),Det1(39),Det2(39),A0(39),A1(39),A2(39),D(39)
10      BEEP
20      INPUT "ENTER  THE FILE NAME",D_file$
30      ASSIGN @File TO D_file$
31      CREATE BDAT "COE",20
32      ASSIGN @File2 TO "COE"
40      BEEP
50      INPUT "ENTER NUMBER OF RUNS STORED",Nrun
60      FOR I=0 TO 39
70      Sx(I)=0
80      Sx2(I)=0
90      Sx3(I)=0
100     Sx4(I)=0
110     Sy(I)=0
120     Sxy(I)=0
130     Sx2y(I)=0
870     NEXT I
880     FOR I=1 TO Nrun
890     ENTER @File:T_bath,T(*)
900     FOR J=0 TO 39
910     D(J)=T_bath-T(J)
920     Sx(J)=Sx(J)+T(J)
930     Sx2(J)=Sx2(J)+T(J)^2
940     Sx3(J)=Sx3(J)+T(J)^3
950     Sx4(J)=Sx4(J)+T(J)^4
960     Sy(J)=Sy(J)+D(J)
970     Sxy(J)=Sxy(J)+D(J)*T(J)
980     Sx2y(J)=Sx2y(J)+D(J)*T(J)^2
990     NEXT J
1000    NEXT I
1010    PRINT "            T/C          A0            A1              A2"
1011    PRINT " "
1020    FOR J=0 TO 39
1030    Det(J)=40*Sx2(J)*Sx4(J)+Sx(J)*Sx3(J)*Sx2(J)*2-Sx2(J)^3-Sx(J)^2*Sx4(J)-40*S
x3(J)^2
1040    Da=Sxy(J)*Sx2(J)*Sx4(J)+Sx(J)*Sx3(J)*Sx2y(J)+Sxy(J)*Sx3(J)*Sx2(J)
1050    Det0(J)=Da-Sx2(J)^2*Sx2y(J)-Sx(J)*Sxy(J)*Sx4(J)-Sy(J)*Sx3(J)^2
1060    De=40*Sxy(J)*Sx4(J)+Sy(J)*Sx3(J)*Sx2(J)+Sx2(J)*Sx2y(J)*Sx(J)
1070    Det1(J)=De-Sx2(J)^2*Sxy(J)-Sx(J)*Sy(J)*Sx4(J)-40*Sx3(J)*Sx2y(J)
1080    Df=40*Sx3(J)*Sx2y(J)+Sx(J)*Sxy(J)*Sx2(J)+Sx(J)*Sx3(J)*Sy(J)
1090    Det2(J)=Df-Sx2(J)^2*Sy(J)-Sx(J)^2*Sx2y(J)-40*Sx3(J)*Sxy(J)
1100    A0(J)=Det0(J)/Det(J)
1110    A1(J)=Det1(J)/Det(J)
1120    A2(J)=Det2(J)/Det(J)
1130    PRINT USING "14X,DD,4X,3(SD.6D,4X)";J+1,A0(J),A1(J),A2(J)
1131    OUTPUT @File2:A0(J),A1(J),A2(J)
1140    NEXT J
1150    END
```

EXPONENT	COEFFICIENT	T/C= 41
0	-3.1930275E-01	
1	1.0128575E+00	
2	-5.4818475E-05	

EXPONENT	COEFFICIENT	T/C= 42
0	-2.2522528E-01	
1	1.0107620E+00	
2	-4.5712065E-05	

EXPONENT	COEFFICIENT	T/C= 43
0	-1.9938344E-01	
1	1.0095769E+00	
2	-4.1260696E-05	

EXPONENT	COEFFICIENT	T/C= 44
0	-2.4667796E-01	
1	1.0108583E+00	
2	-4.6423785E-05	

EXPONENT	COEFFICIENT	T/C= 45
0	-2.5058039E-01	
1	1.0104461E+00	
2	-4.3850226E-05	

EXPONENT	COEFFICIENT	T/C= 46
0	-1.4662748E-01	
1	1.0081341E+00	
2	-3.3403832E-05	

EXPONENT	COEFFICIENT	T/C= 47
0	-2.0144173E-01	
1	1.0087372E+00	
2	-3.5634842E-05	

EXPONENT	COEFFICIENT	T/C= 48
0	-2.8066019E-01	
1	1.0104503E+00	
2	-4.4520679E-05	

EXPONENT	COEFFICIENT	T/C= 49
0	-3.0628157E-01	
1	1.0108137E+00	
2	-4.5446338E-05	

EXPONENT	COEFFICIENT	T/C= 50
0	-2.7662537E-01	
1	1.0102160E+00	
2	-4.2556286E-05	

EXPONENT	COEFFICIENT	T/C= 51
0	-2.4360369E-01	
1	1.0102052E+00	
2	-4.5606545E-05	

EXPONENT	COEFFICIENT	T/C= 52
0	-2.7754513E-01	
1	1.0100960E+00	
2	-4.4413257E-05	

EXPONENT	COEFFICIENT	T/C= 53
0	-3.5887496E-01	
1	1.0114225E+00	
2	-4.7818694E-05	

EXPONENT	COEFFICIENT	T/C= 54
0	-3.2936623E-01	
1	1.0102503E+00	
2	-4.3399839E-05	

EXPONENT	COEFFICIENT	T/C= 55
0	-3.5742917E-01	
1	1.0111652E+00	
2	-4.7246171E-05	

EXPONENT	COEFFICIENT	T/C= 56
0	-4.1638880E-01	
1	1.0117568E+00	
2	-4.8533907E-05	

EXPONENT	COEFFICIENT	T/C= 57
0	-3.6276984E-01	
1	1.0105931E+00	
2	-4.4865618E-05	

EXPONENT	COEFFICIENT	T/C= 58
0	-3.3989581E-01	
1	1.0102587E+00	
2	-4.4930951E-05	

EXPONENT	COEFFICIENT	T/C= 59
0	-3.9258228E-01	
1	1.0109995E+00	
2	-4.6366880E-05	

EXPONENT	COEFFICIENT	T/C= 60
0	-2.9769225E-01	
1	1.0095916E+00	
2	-4.1222481E-05	

EXPONENT	COEFFICIENT	T/C= 61
0	-2.7987174E-01	
1	1.0121568E+00	
2	-4.9924368E-05	

EXPONENT	COEFFICIENT	T/C= 62
0	-1.9282761E-01	
1	1.0102605E+00	
2	-4.2767110E-05	

EXPONENT	COEFFICIENT	T/C= 63
0	-2.1019688E-01	
1	1.0103867E+00	
2	-4.4603609E-05	

EXPONENT	COEFFICIENT	T/C= 64
0	-2.4817587E-01	
1	1.0112909E+00	
2	-4.8233817E-05	

EXPONENT	COEFFICIENT	T/C=	65
0	-1.9101588E-01		
1	1.0104827E+00		
2	-4.5500415E-05		

EXPONENT	COEFFICIENT	T/C=	66
0	-2.6448185E-01		
1	1.0116511E+00		
2	-5.0080800E-05		

EXPONENT	COEFFICIENT	T/C=	67
0	-1.7570321E-01		
1	1.0100325E+00		
2	-4.4527871E-05		

EXPONENT	COEFFICIENT	T/C=	68
0	-2.7670041E-01		
1	1.0119687E+00		
2	-5.0293806E-05		

EXPONENT	COEFFICIENT	T/C=	69
0	-3.3189622E-01		
1	1.0129848E+00		
2	-5.4476114E-05		

EXPONENT	COEFFICIENT	T/C=	70
0	-2.3237513E-01		
1	1.0108945E+00		
2	-4.6776910E-05		

EXPONENT	COEFFICIENT	T/C=	71
0	-3.4055123E-01		
1	1.0121429E+00		
2	-4.9454810E-05		

EXPONENT	COEFFICIENT	T/C=	72
0	-2.2716454E-01		
1	1.0104838E+00		
2	-4.5364118E-05		

EXPONENT	COEFFICIENT	T/C=	73
0	-3.4035121E-01		
1	1.0119056E+00		
2	-4.9277126E-05		

EXPONENT	COEFFICIENT	T/C=	74
0	-3.3760097E-01		
1	1.0126166E+00		
2	-5.3815004E-05		

EXPONENT	COEFFICIENT	T/C=	75
0	-3.5448472E-01		
1	1.0124541E+00		
2	-5.0742084E-05		

EXPONENT	COEFFICIENT	T/C=	76
0	-3.4015128E-01		
1	1.0118546E+00		
2	-4.8928220E-05		

EXPONENT	COEFFICIENT	T/C=	77
0	-2.8240400E-01		
1	1.0108175E+00		
2	-4.7151498E-05		

EXPONENT	COEFFICIENT	T/C=	78
0	-3.3900080E-01		
1	1.0117118E+00		
2	-4.8660568E-05		

EXPONENT	COEFFICIENT	T/C=	79
0	-3.2247594E-01		
1	1.0114324E+00		
2	-4.8182073E-05		

EXPONENT	COEFFICIENT	T/C=	80
0	-2.6107879E-01		
1	1.0098416E+00		
2	-4.0564349E-05		

APPENDIX C

PROGRAM LISTING

```
[illegible]   !JLM
[illegible]   !VERSION 25 JULY 1983
20    !THIS IS A MODIFICATION OF A PROGRAM WRITTEN BY A. WANNIARACHCHI FOR GENER
AL USE ON THE HP3054
30    ! DATA ACQUISITION SYSTEM.MODIFICATIONS DONE BY H. KEEBLER FOR TESTING ON
 THE
40    ! JLM
50    COM /Coe/ A(39),B(39),C(39),D(7)
60    DIM Em(39),T(39),Emf(39)
91    ASSIGN #Coe TO "COE"
92    FOR I=0 TO 39
93    ENTER #Coe;A(I),B(I),C(I)
94    NEXT I
95    DATA 0,10086091,25727.94369,-767345.2295,78025595.81
105   DATA -9247486589,6.97688E+11,-2.66192E+13,3.94078E+14
106   READ D(*)
110   BEEP
120   PRINTER IS 701
130   CLEAR 709
131   INPUT "ENTER RESISTOR VOLTAGE",Rv
132   INPUT "ENTER LOAD VOLTAGE",Lv
133   Amp=Rv/2.0
134   Pow=Amp*Lv
136   PRINT "RESISTOR VOLTAGE=",Rv,"VOLTS"
137   PRINT "LOAD VOLTAGE=        ",Lv,"VOLTS"
138   PRINT "CURRENT=             ",Amp,"AMPS"
139   PRINT "POWER=               ",Pow,"WATTS"
141   INPUT "ENTER MONTH,DATE, AND TIME (MM:DD:HH:MM:SS)",Time$
150   OUTPUT 709;"TD";Time$
160   BEEP
170   INPUT "ENTER INPUT MODE(1=3054A-AUTO,2=FILE,3=MANUAL)",Im
180   IF Im=2 THEN
190   BEEP
200   INPUT "ENTER NAME OF EXISTING DATA FILE",Oldfile$
210   PRINT USING "10X,""THESE RESULTS ARE FROM DATA FILE"",10A";Oldfile$
220   ASSIGN #File TO Oldfile$
230   END IF
240   IF Im=1 OR Im=3 THEN
250   BEEP
260   INPUT "NEW DATA FILE NAME?",Newfile$
270   CREATE BDAT Newfile$,30
280   ASSIGN #File TO Newfile$
281   INPUT "enter number of samples",It
282   INPUT "ENTER WAIT TIME IN SEC",W_time
290   END IF
300   BEEP
310   J=0
330   OUTPUT 709;"AR AF40 AL79"
340   OUTPUT 722;"F1 R1 T1 Z1 FL1"
350   J=J+1
360   IF Im=1 OR Im=3 THEN
361   !READ TEMP OF BOX WALL(INSIDE)
362   PRINT " "
364   PRINT "INSIDE BOX WALL TEMP"
370   FOR I=0 TO 9
380   OUTPUT 709;"AS SA"
390   ENTER 722;Emf(I)
391   IF I<4 THEN 400
392   IF I>5 THEN 400
394   IF Emf(I)<.00001 THEN 400
```

```
395   CALL Tvsv(Emf(I),Emf1(I))
396   Tt=Emf1(I)
397   T(I)=FNTem(Tt,I)
399   PRINT T(I),I+41,J
400   NEXT I
401   !PRINT "INTERNAL AIR TEMP"
410   !READ AIR TEMP MODEL
420   FOR I=10 TO 11
430   OUTPUT 709;"AS SA"
440   ENTER 722;Emf(I)
441   IF Emf(I)<.0001 THEN 450
442   CALL Tvsv(Emf(I),Emf1(I))
443   Tt=Emf1(I)
444   !  T(I)=FNTem(Tt,I)
445   ! PRINT T(I),I+41,J
450   NEXT I
451   PRINT " "
452   PRINT "ULM U1,U11,U13-EPROM/CHIP"
454   !FOR ACTUAL
455   FOR I=12 TO 19
456   OUTPUT 709;"AS SA"
457   ENTER 722;Emf(I)
458   IF Emf(I)<.00001 THEN 464
459   CALL Tvsv(Emf(I),Emf1(I))
460   Tt=Emf1(I)
461   T(I)=FNTem(Tt,I)
462   PRINT T(I),I+41,J
464   NEXT I
465   PRINT " "
466   !  PRINT "I/O MODEL U2,U1,U10,U11,U12,U13"
467   !READ I/O BOARD   TEMP
470   FOR I=20 TO 31
480   OUTPUT 709;"AS SA"
490   ENTER 722;Emf(I)
491   IF Emf(I)<.00001 THEN 500
492   CALL Tvsv(Emf(I),Emf1(I))
493   Tt=Emf1(I)
494   !  T(I)=FNTem(Tt,I)
495   !  PRINT T(I),I+41,J
500   NEXT I
501   PRINT " "
502   PRINT " ULM U3, INTERNAL AIR,FRONT WALL"
510   !READ ACT BOARD TEMP
520   FOR I=32 TO 37
530   OUTPUT 709;"AS SA"
540   ENTER 722;Emf(I)
541   IF Emf(I)<.00001 THEN 550
542   CALL Tvsv(Emf(I),Emf1(I))
543   Tt=Emf1(I)
544   T(I)=FNTem(Tt,I)
545   PRINT T(I),I+41,J
550   NEXT I
551   PRINT " "
552   PRINT "EXTERNAL BOX TEMP"
554   !READ OUTSIDE BOX TEMP
555   FOR I=38 TO 39
556   OUTPUT 709;"AS SA"
557   ENTER 722;Emf(I)
558   IF Emf(I)<.00001 THEN 565
560   CALL Tvsv(Emf(I),Emf1(I))
```

```
10     !MODEL
11     !VERSION 13 AUG 1983
20     !THIS IS A MODIFICATION OF A PROGRAM WRITTEN BY A. WANNIARACHCHI FOR GENER
AL USE ON THE HP3054
30     !  DATA ACQUISITION SYSTEM.MODIFICATIONS DONE BY H. KEEBLER FOR TESTING ON
 THE
40     !  ULM
50     COM /Co/ A(39),B(39),C(39),D(7)
60     DIM Emf(39),T(39),Emf1(39)
91     ASSIGN #Coe TO "COE"
92     FOR I=0 TO 39
93     ENTER #Coe;A(I),B(I),C(I)
94     NEXT I
95     DATA 0.10086091,25727.94369,-767345.8295,78025595.81
105    DATA -9247486589.6.97688E+11,-2.66192E+13,3.94078E+14
106    READ D(*)
110    BEEP
120    PRINTER IS 701
130    CLEAR 709
131    INPUT "ENTER RESISTOR VOLTAGE",Rv
132    INPUT "ENTER LOAD VOLTAGE",Lv
133    Amp=Rv/2.0
134    Pow=Amp*Lv
135    PRINT "                    MODEL OF ULM "
137    PRINT "RESISTOR VOLTAGE=",Rv,"VOLTS"
138    PRINT "LOAD VOLTAGE=     ",Lv,"VOLTS"
139    PRINT "CURRENT=          ",Amp,"AMPS"
140    PRINT "POWER=            ",Pow,"WATTS"
141    INPUT "ENTER MONTH,DATE, AND TIME (MM:DD:HH:MM:SS)",Time$
150    OUTPUT 709:"TD";Time$
160    BEEP
170    INPUT "ENTER INPUT MODE(1=3054A-AUTO,2=FILE,3=MANUAL)",Im
180    IF Im=2 THEN
190    BEEP
200    INPUT "ENTER NAME OF EXISTING DATA FILE",Oldfile$
210    PRINT USING "10X,""THESE RESULTS ARE FROM DATA FILE"",10A";Oldfile$
220    ASSIGN #File TO Oldfile$
230    END IF
240    IF Im=1 OR Im=3 THEN
250    BEEP
260    INPUT "NEW DATA FILE NAME?",Newfile$
270    CREATE BDAT Newfile$,40
280    ASSIGN #File TO Newfile$
281    INPUT "enter number of samples",It
282    INPUT "ENTER WAIT TIME IN SEC",I_time
290    END IF
300    BEEP
310    J=0
330    OUTPUT 709:"AR AF40 AL79"
340    OUTPUT 722:"F1 R1 T1 Z1 FL1"
350    J=J+1
360    IF Im=1 OR Im=3 THEN
361    !READ TEMP OF BOX WALL(INSIDE)
362    PRINT " "
364    PRINT "INSIDE BOX WALL TEMP(45,46)"
365    PRINT "CPU-U3,BOARD(BOT/TOP)"
370    FOR I=0 TO 9
380    OUTPUT 709:"AS SA"
390    ENTER 722:Emf(I)
```

```
394   IF Emf(I)<.00001 THEN 402
395   CALL Tvsv(Emf(I),Emf1(I))
396   Tt=Emf1(I)
397   T(I)=FNTem(Tt,I)
398   IF I=5 THEN T(I)=0.
400   IF I=5 THEN 402
401   PRINT T(I),I+41,J
402   NEXT I
403   PRINT "INTERNAL AIR TEMP/AMBIENT(53)"
410   !READ AIR TEMP MODEL
420   FOR I=10 TO 12
430   OUTPUT 709:"AS SA"
440   ENTER 722:Emf(I)
441   IF Emf(I)<.0001 THEN 450
442   CALL Tvsv(Emf(I),Emf1(I))
443   Tt=Emf1(I)
444   T(I)=FNTem(Tt,I)
445   PRINT T(I),I+41,J
450   NEXT I
451   PRINT " "
452   !  PRINT "ULM U1,U11,U13-EPROM/CHIP"
454   !FOR ACTUAL
455   FOR I=13 TO 19
456   OUTPUT 709:"AS SA"
457   ENTER 722:Emf(I)
458   IF Emf(I)<.00001 THEN 464
459   CALL Tvsv(Emf(I),Emf1(I))
460   Tt=Emf1(I)
461   !  T(I)=FNTem(Tt,I)
462   !  PRINT T(I),I+41,J
464   NEXT I
465   PRINT " "
466   PRINT "I/O MODEL U2,U1,U10,U11,U12,U13"
467   !READ I/O BOARD   TEMP
470   FOR I=20 TO 31
480   OUTPUT 709:"AS SA"
490   ENTER 722:Emf(I)
491   IF Emf(I)<.00001 THEN 500
492   CALL Tvsv(Emf(I),Emf1(I))
493   Tt=Emf1(I)
494   T(I)=FNTem(Tt,I)
495   PRINT T(I),I+41,J
500   NEXT I
501   PRINT " "
502   !  PRINT " ULM U3, INTERNAL AIR"
510   !READ ACT BOARD TEMP
520   FOR I=32 TO 37
530   OUTPUT 709:"AS SA"
540   ENTER 722:Emf(I)
541   IF Emf(I)<.00001 THEN 550
542   CALL Tvsv(Emf(I),Emf1(I))
543   Tt=Emf1(I)
544   !  T(I)=FNTem(Tt,I)
545   !  PRINT T(I),I+41,J
550   NEXT I
551   Tt=Emf1(36)
552   T(36)=FNTem(Tt,36)
555   PRINT "EXTERNAL BOX TEMP"
556   !READ OUTSIDE BOX TEMP
557   FOR I=38 TO 39
```

```
561   It=Emf(I)
562   T(I)=FNTem(It,I)
563   PRINT T(I),I+41,
565   NEXT I
566   OUTPUT @File;Emf(*)
570   ELSE
580   ENTER @File;Emf(*)
590   END IF
600   PRINT " "
601   PRINT "AMBIENT AIR= ",T(36),"77"
610   PRINT "SUMMARY"
620   Jmax=0
650   IF Im=1 OR Im=3 THEN
661   Tmax=0
670   FOR I=0 TO 39
671   !PRINT T(I),I+41,
680   IF T(I)>Tmax THEN Tmax=T(I)
681   IF Tmax=T(I) THEN Jmax=I
690   NEXT I
691   PRINT "TMAX=",Tmax,Jmax+41
692   OUTPUT 709;"TD"
693   ENTER 709;Time$
695   PRINT USING "10X,""Month, DATE, AND TIME: "",15A";Time$
696   IF Im=3 THEN 705
698   IF (J+1)>It THEN 711
700   IF Tmax>250 THEN 711
702   WAIT I_time
703   IF Tmax<250 THEN 350
705   END IF
706   INPUT "enter 1 for new data, 2 to end",Flag
707   IF Flag=1 THEN 350
711   OUTPUT 709;"TD"
712   ENTER 709;Time$
714   PRINT USING "10X,DD,""data runs are stored  in file"",10A";J,Newfile$
715   PRINT USING "10X,""Month, DATE, AND TIME: "",15A";Time$
720   END
730   SUB Tvsv(V,T)
740   COM /Co/ A(39),B(39),C(39),D(7)
750   Sum=0
760   FOR I=0 TO 7
770   Sum=Sum+D(I)*V^I
780   NEXT I
790   T=(Sum*9/5)+32
800   SUBEND
810   !THIS FUNCTION USES CALIBRATION COEFICIENTS
820   !TO ADJUST THERMOCOUPLE READINGS
830   DEF FNTem(T,I)
840   COM /Co/ A(39),B(39),C(39),D(7)
850   Delta=A(I)+T*(B(I)+T*C(I))
860   T=T+Delta
870   RETURN T
880   FNEND
```

APPENDIX D

ULM DATA RUN 1 AUG 83

A. LOCATION: Root Hall, Room 107

B. CONDITIONS:

1. Backpack placed in the environmental chamber in a vertical position.

2. Initial temperature: 48.3C

C. CONDUCT OF RUN:

1. Part I - 8 samples were taken at 5 minute intervals.

   Initial electrical readings were as follows:

   resistor voltage = 3.053
   load voltage = 5.3
   current (amps) = 1.53
   power (watts) = 8.09

2. Part II - 20 samples were taken at 30 minute intervals. Electrical readings (same as settings as part I) were as follows:

   resistor voltage = 2.88
   load voltage = 5.27
   current (amps) = 1.44
   power (watts) = 7.59

THIS DATA IS FROM 1 AUG 83 -ULM

TIME(MIN)	TC= 53	TC= 54	TC= 55
0	47.8441040866	47.9501080717	55.1470236239
5	50.0519163325	50.2542632526	60.5554476882
10	51.9587254154	52.1449375838	63.1962387395
15	53.3484079473	53.5005109174	64.8282906294
20	54.4157701349	54.5551730048	65.9791736115
25	55.2440257037	55.3733415172	66.8864085739
30	55.9340346794	56.0534698763	67.5875183775
35	56.5003721356	56.6169181363	68.1355276816
40	57.5479035191	57.5542438633	69.1522717308
70	58.7460233795	58.8443215125	70.3133923531
100	59.2656585865	59.3497301723	70.7842003465
130	59.8447832523	59.9421979306	71.7834172501
160	60.1145335545	60.2153244853	72.0611767063
190	60.2412953484	60.3291621641	72.1740524784
220	60.2574256552	60.3475825413	72.1943674630
250	60.289687906	60.3913285744	72.3275261539
280	60.2781662393	60.3775143962	72.3275261539
310	60.2620355165	60.3590949776	72.3049589994
340	60.2389908389	60.3222543706	72.2346478223
370	60.2666443408	60.3567925083	72.3139959547
400	60.356509004	60.4511861797	72.401991641
430	60.4417521965	60.5363574277	72.4899841954
460	60.5292360637	60.6284202833	72.5779636242
490	60.5799574572	60.6997588763	72.6299427935
520	60.6605618098	60.7595844337	72.7020149232
550	60.7112216046	60.8148025123	72.7606492795
580	60.7664817326	60.853912117	72.7989823274
610	60.7825982673	60.8907187325	72.8260401571

TIME(MIN)	TC= 56	TC= 57	TC= 58
0	59.2646601061	54.2242673643	53.6747652633
5	64.7564593407	62.7103743992	61.9641893526
10	67.2589145273	66.4822041173	65.5958764609
15	68.860682052	68.5179772	67.5726553826
20	70.0040787045	69.8221577964	68.8558037413
25	70.8941117788	70.768429091	69.7965093429
30	71.5884427722	71.4963408179	70.5050112685
35	72.1238975223	72.0541004269	71.0635158632
40	73.1031756465	73.0531389558	72.0368079486
70	74.2541184082	74.1944448031	73.181328865
100	74.6882367736	74.6418138627	73.636657536
130	75.8316159961	75.8316596382	74.7854319011
160	76.096367814	76.0940035074	75.0391663695
190	76.2130006293	75.2015983501	75.1514036991
220	76.2242141157	76.2352177546	75.1873151699
250	76.3879059042	75.4077575161	75.3421505479
280	76.3901489579	75.4077675161	75.3375708014
310	76.3632437549	76.3965645025	75.326451637
340	76.3363373329	76.3539911304	75.2838165017
370	76.3834227714	76.3920832331	75.326451637
400	76.4596484249	76.4727408437	75.3937640493
430	76.5403472793	76.5690675738	75.4947183871
460	76.6299998174	76.6317335916	75.5664977167
490	76.697230344	75.7056904318	75.627054791
520	75.744297187	76.7661528535	75.6898482112
550	76.8137452408	76.8288481513	75.7459081666
580	76.8518316951	75.3646710777	75.7929944487
610	76.8787147817	76.8937756215	75.8086890483

TIME(MIN)	TC= 59	TC= 60	TC= 73
0	52.9230399384	53.4915719066	60.4794925494
5	59.1196371873	59.7441540964	67.00991744[illegible]
10	62.0804306303	62.7087069186	69.50182708[illegible]
15	63.8665340167	64.4664793469	70.319[illegible]
20	65.064877772	65.6512549459	71.8927982524
25	65.9551732575	66.546978552[illegible]	72.6650662[illegible]
30	66.6595960994	67.2433880434	73.2572744[illegible]
35	67.2038581594	67.7981037046	73.7359847[illegible]
40	68.1977063118	68.7638677536	74.62506[illegible]
70	69.3373030142	69.9189303102	75.6799661244
100	69.802040415[illegible]	70.3761201091	76.06500249[illegible]
130	70.7756634536	71.3639319243	77.331325[illegible]
160	71.0299941213	71.5281873299	77.5753152[illegible]
190	71.1488358459	71.7455741751	77.6670651[illegible]
220	71.1759664376	71.7929708175	77.66930277[illegible]
250	71.3138609717	71.9329935233	77.8818354[illegible]
280	71.3002990053	71.9135846455	77.8684174[illegible]
310	71.2980386472	71.9058148651	77.8432[illegible]
340	71.2709136744	71.8764782573	77.8235786417
370	71.3002990053	71.9103280606	77.8722[illegible]
400	71.3771460232	71.995072254	77.9511758242
430	71.4630220148	72.0772921688	78.038395[illegible]
460	71.5466250965	72.1539896624	78.1300705829
490	71.6031086323	72.2148294371	78.2016176[illegible]
520	71.6753983967	72.2780381615	78.2552702173
550	71.7296098897	72.3389252147	78.3200935[illegible]
580	71.7725337971	72.3930417394	78.3670302962
610	71.8064009931	72.4246075302	78.33267506[illegible]

TIME(MIN)	TC= 74	TC= 75	TC= 76
0	57.768527767	49.7411491201	49.4412268862
5	64.2325309951	53.3177246146	51.9822399329
10	66.7185211319	55.2661529747	53.5479774681
15	68.1463249777	56.5582684882	54.6689145319
20	69.1303059733	57.5323705708	55.5343046684
25	69.8995147097	58.3150763113	56.2405204037
30	70.5159637076	58.939540499	56.3159909275
35	70.9937168594	59.4640231928	57.2981930797
40	71.8960795617	60.3962719992	58.1919645693
70	72.9459529555	61.501921446	59.2552500991
100	73.3566139085	61.9596803176	59.5961628347
130	74.5273724097	62.7616033272	60.3718752554
160	74.7590464793	63.0095364257	60.616135862
190	74.8557377972	63.12987254	60.7129921702
220	74.8692283461	63.1426416153	60.7405209639
250	75.0445773522	63.2160657909	60.7912013063
280	75.0333385979	63.2229488273	60.7754789947
310	75.0108604456	63.1977106246	60.7543493698
340	74.9816375645	63.174765844	60.7313165192
370	75.0288430361	63.2252431545	60.7912013068
400	75.1187477508	63.2986568004	60.871805565
430	75.1974031172	63.3995852891	60.9685157151
460	75.2827284795	63.475270055	61.0421865934
490	75.3524357926	63.5417727052	61.1056447856
520	75.4063506383	63.6059748809	61.1756968479
550	75.4669929425	63.674754993	61.2378365985
580	75.5231492141	63.7127267481	61.2861528635
610	75.5366244831	63.7320654862	61.2976685174

TIME(MIN)	TC= 77	TC= 78	TC= 79
0	48.0603555101	47.3664507086	47.9508227469
5	48.1074329693	48.7047198126	47.9861555411
10	48.1309701872	49.5980955848	48.0356176345
15	48.1262628242	50.3891718085	48.0685898893
20	48.1427384183	51.0690158289	48.1133347346
25	48.1333238536	51.6427208867	48.1415929412
30	48.1709811454	52.1363353671	48.1527854302
35	48.1497992351	52.5547465453	48.1886363726
40	48.1351019549	53.3462958865	48.2297127039
70	48.1968690376	54.2998119748	48.2828613361
100	48.2156958303	54.7049725346	48.2875696603
130	48.2815845303	55.1098415058	48.3652511938
160	48.243934811	55.3261175371	48.3911425053
190	48.1709811454	55.4144647374	48.3417124375
220	48.1050791921	55.4214389142	48.261673375
250	47.9449986902	55.4167894726	48.1486571284
280	47.9661884931	55.4028409177	48.1439476127
310	47.862586131	55.3795925595	48.059169447
340	48.067417386	55.3633181383	48.1674947834
370	48.2557006251	55.4260883175	48.3252348072
400	48.3357014881	55.505122309	48.4254471085
430	48.4580332572	55.5957553119	48.5088154701
460	48.4627377824	55.6678044917	48.5441124227
490	48.5074287663	55.7398344769	48.6217577521
520	48.5850413291	55.8141783704	48.6323349143
550	48.646132919	55.8722527257	48.7605509079
580	48.6297223893	55.9140625655	48.7246758704
610	48.6038548488	55.921030571	48.7135062993

TIME(MIN)	TC= 80	TC= 72	TC= 71
0	47.7228550225	46.682655042	47.9567490852
5	48.1535718775	48.1978434802	48.0439512588
10	48.710888075	50.623359328	48.0629039774
15	49.274689037S	45.551192061	48.0887250852
20	49.8168080979	49.2346260592	48.076943077
25	50.2576242103	49.8707795711	48.1122892429
30	50.6676457146	57.369783629	48.0981510496
35	51.0165128393	49.6572442548	48.1028638212
40	51.6663387636	51.3468451162	48.1254270721
70	52.4868587403	51.566748334	48.1617700525
100	52.3462625708	53.4067982254	48.1711944632
130	53.1751261925	49.7792739431	48.2324491907
160	53.3662920665	46.7817531305	48.2348050053
190	53.4245614679	57.2727223055	48.1429207461
220	53.4315533919	50.3773002908	48.076943077
250	53.4129080687	49.1884306227	47.9251071901
280	53.2779464279	46.2482991922	47.9072497387
310	53.2756155749	50.0255981512	47.8530311484
340	53.3220032954	48.6800368189	48.0086007022
370	53.4262921188	48.9503511219	48.2018229309
400	53.5131194425	49.1171748001	48.2724966655
430	53.5806938186	49.6009133075	48.366714505
460	53.6552492579	46.935084015	48.4020429307
490	53.7437710892	55.0502633902	48.4632710964
520	53.8020015694	51.8590387435	48.5632291384
550	53.8905004145	49.2943197559	48.5645194149
580	53.8974865755	47.7858608248	48.5645194149
610	53.8998152767	46.7416441393	48.5456839175

APPENDIX E

ULM DATA RUN 12 AUG 83

A. LOCATION: Ft. Hunter Liggett Ca.

B. CONDITIONS:

1. The backpack was placed on a concrete slab outside in direct sunlight in an upright position.

2. Initial temperature: 23.8 deg C

C. CONDUCT OF RUN:

1. Part I - 10 samples were taken at 3 minute intervals. Initial electrical setting was at zero to check the effect of solar radiation on the internal temperature of the backpack.

   resistor voltage = 0.0
   load voltage = 0.0
   current (amps) = 0.0
   power (watts) = 0.0

2. Part II - 15 samples were taken at 5 minute intervals. Electrical readings were as follows:

   resistor voltage = 3.05
   load voltage = 5.21
   current (amps) = 1.52
   power (watts) = 7.93

3. Part III - 10 samples were taken at 15 minute intervals. Electrical readings (w/same setting as part II) were as follows:

   resistor voltage = 2.86
   load voltage = 5.29
   current (amps) = 1.43
   power (watts) = 7.56

4. Part IV - 8 samples were taken at 15 minute intervals. Orientation was changed to maintain the direct nature of the sun's rays. This caused the backpack to be moved to a position on dirt rather than the concrete slab. Electrical readings (w/same setting as part II were as follows:

resistor voltage = 2.82
load voltage = 5.28
current (amps) = 1.41
power (watts) = 7.44

THIS DATA IS FROM 12 AUG 83 -ULM

TIME(MIN)	TC= 53	TC= 54	TC= 55
0	24.7505274812	24.8202072084	24.6300455123
3	25.7790354263	25.8572816249	25.6415034125
6	26.749846169	26.8382921855	26.640795652
9	27.6898374478	27.7684672344	27.5621950827
12	28.5606330198	28.6505370614	28.4403311482
15	29.4055218448	29.4959452517	29.302003[illegible]
18	30.263610772	30.3462059482	30.15205170[illegible]
21	31.0716138195	31.1539524516	30.97564[illegible]
24	31.8540545667	31.9307137737	31.75562[illegible]
27	32.5940819256	32.6772460615	32.519[illegible]
35	34.2594819034	34.5460390202	42.796[illegible]
40	37.5767123727	37.8922342882	48.55[illegible]
45	40.2809449799	40.5663570155	51.75[illegible]
50	42.4268528515	42.6760953648	54.0876[illegible]
55	44.2062071733	44.4484611008	55.3180160563
60	45.7574688251	45.3789058732	57.520254[illegible]
65	47.1580921032	47.3684425915	58.9576349053
70	48.3974751948	48.5946399075	60.192485201
75	49.4602709299	49.6562440617	61.2445499802
80	50.4084753949	50.5588985915	62.1339521686
85	51.2801450295	51.4226504075	63.0059522614
90	52.1831770563	52.3666129177	63.8766288225
95	53.0684136373	53.2511069131	64.702553547
100	53.9406017429	54.1014238837	65.5159005232
105	54.7275722225	54.8644527058	66.3030256487
115	55.4346311331	55.5498054091	66.9729547098
130	56.7359310748	56.8625274241	68.24461744[illegible]
145	57.9221316908	58.0620541785	69.4091998323
160	58.7113641955	58.8397644029	70.177512893[illegible]
175	59.2448822574	59.3405040513	70.514481489
190	59.3395228592	59.4212275857	70.7140558236
205	59.2887425103	59.358956146	70.6439029037
220	59.4756879251	59.5525673324	70.8225631456
235	59.7271599795	59.8259796973	71.0918223662
250	60.3173389608	60.4143514669	71.6501356177
255	60.4137147462	60.5041319507	71.708870611[illegible]
280	61.0012779175	61.1023111812	72.2146817486
295	61.6637141195	61.7595926	72.7989823274
310	62.3047223465	62.4138329136	73.4300090625
325	63.3141847481	63.3926642218	74.3325585389
340	63.6098064631	63.7017874389	74.6361000839
355	63.7518344414	63.8093695124	74.7507308831
370	62.7431377907	62.789973052	73.824059039

TIME(MIN)	TC= 56	TC= 57	TC= 58
0	24.5605910262	24.0285427841	24.2108088404
3	25.5649553789	25.0330727016	25.19991[illegible]
5	26.555008818	25.0222867812	25.1698656452
9	27.4696027387	26.9598730575	27.09874894[illegible]
12	28.3433960367	27.86221485	27.3843540023
15	29.2010203296	28.730760649	28.8415560985
18	30.0498741694	29.5820834867	29.6924206795
21	30.870540251	30.4052095381	30.51025603[illegible]
24	31.6558704294	31.2027092061	31.00005[illegible]99
27	32.415734675	31.9771319647	32.0571[illegible]
35	46.9613425262	41.5308910534	40.0261725465
40	52.7398243739	50.2132710082	47.81643872[illegible]
45	55.8720955705	54.5686647556	51.78253079[illegible]4
50	58.1483921073	57.2607604305	54.3265597407
55	59.9661207607	59.2276581299	56.2241511347
60	61.5596694548	60.8589280992	57.81720273[illegible]4
65	62.9882591552	62.3124797597	59.2489994[illegible]
70	64.1844472581	63.5399910209	60.4494067199
75	65.2205131273	64.6153497107	61.4865090642
80	66.0973301624	65.5038784151	62.3910117049
85	66.9454827956	66.0568693677	63.2299679157
90	67.8106023861	67.2154431338	64.1029[illegible]4
95	68.6380954314	68.0454897158	64.9453548918
100	69.448529572	68.8562080605	65.7487005509
105	70.2012252456	69.6126832297	66.52[illegible]4
115	70.8438500207	70.2796065754	67.1837495005
130	72.1103477099	71.5799253843	68.44[illegible]
145	73.2564637567	72.7037799553	69.5654[illegible]
160	73.9795372186	73.4630912487	70.2377978[illegible]
175	74.4723420531	73.9695089315	70.796755964[illegible]
190	74.5892948029	74.0954825201	70.88946[illegible]
205	74.4993332002	74.0235013147	70.8713776634
220	74.6679999923	74.1989426514	71.0431747965
235	74.9310242378	74.4395278791	71.370806871
250	75.4859146318	74.9945257862	71.9059246553
265	75.4904055517	75.0955829892	72.090952075
280	75.9640066691	75.5557375666	72.60062[illegible]
295	76.5201735935	76.1321122363	73.16391254[illegible]
310	77.1541963483	76.716887639	73.77165[illegible]
325	78.0178832599	77.5910592325	74.6349363856
340	78.3062522778	77.8713113646	74.39322815[illegible]
355	78.435858843	78.0500921686	74.9942655032
370	77.5459218565	77.2608187763	74.1652350334

TIME(MIN)	TC= 59	TC= 60	TC= 72
0	24.7344327394	24.7532140491	20.952029885
3	25.7230713335	25.7579964545	21.651053098
6	26.7048330707	26.7166600571	21.2942347573
9	27.6112395902	27.6392570615	22.4480057124
12	28.4769136194	28.5040258563	21.8467048697
15	29.3362193143	29.3600034395	22.2090698144
18	30.1818884473	30.2023735929	23.2979579619
21	31.0018378659	31.0214933695	22.6605331492
24	31.7694940684	31.793228685	23.2164861144
27	32.5238793749	32.5492751944	23.2979578519
35	40.4641879591	41.0468732013	23.5867025365
40	47.0581615869	47.7034452009	23.5955711918
45	50.7180808049	51.3701332824	24.0355220136
50	53.1936760802	53.8525170453	24.0281272351
55	55.0751900976	55.7210890994	24.346002197
60	56.6630691325	57.3105749921	24.7153552517
65	58.0846709482	58.7156449799	24.9162752945
70	59.2766356147	59.9008056934	25.5663066979
75	60.3348463455	60.9524935922	25.1704201516
80	61.2209496082	61.8576659154	26.6855445519
85	62.0666522798	62.5949533805	27.059305980
90	62.9478042509	63.5676575119	28.2839396511
95	63.7909828599	64.3910590595	29.7846815149
100	64.6009274806	65.2087346753	28.6332903734
105	65.3777778635	65.9910783131	29.3520900537
115	66.0441279566	66.5631042233	29.8139113057
130	67.3176563855	67.9094284337	29.3337029359
145	68.4748639558	69.0193614452	31.1254575308
160	69.2125547622	69.7536212215	29.696948331
175	69.7000563829	70.2426210251	29.899179773
190	69.8020404151	70.3331321689	31.3927048183
205	69.7680477052	70.3105056219	33.1433579319
220	69.890412263	70.4417272579	34.0188688174
235	70.1871538057	70.7538271478	33.1046263654
250	70.7485144243	71.2984768989	34.0382003586
265	70.7392375078	71.2736292707	36.9153942292
280	71.3206418379	71.8381128121	34.7095231761
295	71.3967306755	72.4336260022	33.7968338913
310	72.5331630745	73.0398043452	36.8312797171
325	73.4189646094	73.9467906637	34.9363206201
340	73.7026815563	74.2458157301	35.9340186217
355	73.7814677026	74.3424609218	36.3960718339
370	72.8669031264	73.4315759393	35.9219805218

TIME(MIN)	TC= 56	TC= 57	TC= 58
0	24.5605910262	24.0235427841	24.2108088404
3	25.5649553789	25.0330727016	25.1999130174
6	26.555008818	26.0232867812	26.1698656453
9	27.4696027387	26.9698790575	27.0987489422
12	28.3423960367	27.8633221385	27.9843540023
15	29.2010203296	28.730760649	28.8415560905
18	30.0498741694	29.5820834867	29.6924286795
21	30.870540251	30.4052095381	30.5102560361
24	31.6558704294	31.2027092061	31.3000588139
27	32.415734675	31.9771313647	32.0571201915
35	46.9613425252	41.5328913524	40.0251725465
40	52.7393840739	50.2132710082	47.816438792
45	55.8720955795	54.5686647556	51.7825807814
50	58.1483921073	57.2607604905	54.3265637407
55	59.9661207607	59.2276681289	56.2241511047
60	61.5596594548	60.8589280892	57.8172037314
65	62.3862531552	62.3134737597	59.2489994143
70	64.1844472581	63.5399910209	60.4494067199
75	65.2205181273	64.6153497137	61.4865097642
80	66.0973301624	65.5038784151	62.3910117849
85	66.9454827956	66.3562693677	63.2299679157
90	67.8106023861	67.2154431938	64.1020191314
95	68.6380954314	68.0454897168	64.9453548919
100	69.448539572	68.8562080605	65.7487906509
105	70.2012252456	69.6136822267	66.5213319504
115	70.3488500307	70.2786355754	67.1837495035
130	72.1103477099	71.5799253869	68.4427775278
145	73.2564637567	72.7037799663	69.5654392159
160	73.9795372136	73.4630912497	70.2877978669
175	74.4723420531	73.9695089315	70.7967559641
190	74.5892948029	74.0954835201	70.8894639135
205	74.4993332002	74.0205012147	70.8713776694
220	74.6679999923	74.1989426514	71.0431747965
235	74.9310242373	74.4395278791	71.370806871
250	75.4859146318	74.9945257862	71.9059246553
265	75.4904055517	75.0955829892	72.090958075
280	75.9640066691	75.5557375665	72.6006286661
295	76.5201735935	75.1321122363	73.1639125433
310	77.1541963483	76.716887609	73.7716582913
325	78.0179382599	77.5910592325	74.6349363856
340	78.3062522778	77.8713113646	74.8932261501
355	78.435858843	78.0500921636	74.9942655032
370	77.5459218565	77.2608187763	74.1652350334

TIME(MIN)	TC= 73	TC= 74	TC= 75
0	24.6250659578	24.7165772347	25.0154785665
3	25.6123548987	25.6992631727	25.9655621549
6	26.5240237585	26.6259725203	26.3892755454
9	27.4070610657	27.5141712424	27.7475735891
12	28.2616240385	28.3714175948	29.5897188661
15	29.092747886	29.2125341072	29.435333702
18	29.9151838737	30.0278498242	30.2649018514
21	30.6924585947	30.8199290628	31.0614679531
24	31.4612498981	31.5937474589	31.320329895
27	32.1948968269	32.3299678343	32.5586477296
35	47.9507195638	45.2520117008	35.3921154521
40	54.4096438967	5 .2413975479	40.3556027987
45	57.4341542255	54.1556445491	43.0243043999
50	59.4784981967	56.1636046343	45.0758149457
55	61.0852349557	57.7708437198	46.741688223
60	62.5497303932	59.2210822152	48.2375778663
65	63.8730740475	60.5316624385	49.5672366804
70	65.0150855839	61.6575500748	50.750639311
75	65.9859684171	62.641171838	51.7442451653
80	66.8298877888	63.4740900199	52.6449218344
85	67.6475494136	64.2974848087	53.4998025642
90	68.489066469	65.1568885489	54.4638865345
95	69.3180254888	65.988458253	55.3405997577
100	70.0959510421	66.7800780556	56.1449277294
105	70.8502101301	67.5136974998	56.9341922102
115	71.4768893651	68.1440505746	57.5128318974
130	72.6831188943	69.3641258377	58.7777032153
145	73.7652668044	70.4570655656	60.0318609255
160	74.4518523933	71.1498641806	60.7834923379
175	74.8926475611	71.6044905187	61.3223986319
190	74.9668307815	71.6429252965	61.4766075315
205	74.9106322251	71.5909247	61.667584927
220	75.2005595187	71.828281122	61.6537814648
235	75.4656400542	72.0881325047	61.964279056
250	76.0044212429	72.6142607899	62.4928884832
265	76.0492975769	72.572632522	62.9314949349
280	76.5158102749	73.0790283585	63.2986568004
295	77.0469190087	73.6448256401	63.757290299
310	77.660352161	74.2663486249	64.3781338901
325	78.5346313863	75.1120053733	65.2247179206
340	78.7356904388	75.3254765193	65.3413121429
355	78.867458995	75.4085969831	65.2201451197
370	78.0137961591	74.5611170282	64.3918721743

TIME(MIN)	TC= 76	TC= 77	TC= 78
0	25.7860711488	33.0971990241	27.0383233603
3	26.7341994544	34.0454006106	27.944780163
6	27.6315314518	34.4850451503	28.7565181448
9	28.4661194702	35.5873453505	29.5332372752
12	29.301760646	36.3024637318	30.3670012066
15	30.1335790441	36.9517317143	31.1677782739
18	30.9275291933	37.8169918927	31.9041575953
21	31.700801112	38.4228211708	32.6564507716
24	32.4462130991	38.9856307805	33.3519449882
27	33.1420830756	39.359009537	33.9908728446
35	36.5039157022	40.119132291	35.2542975139
40	39.738976808	40.8472781213	36.8106246234
45	42.015587933	42.2742063956	38.4486719398
50	43.885355295	42.4550942715	40.0051359536
55	45.4430815002	43.2488367892	41.3543635418
60	46.3760562408	43.8992097708	42.8145400134
65	48.168384112	44.9377124995	43.7720559119
70	49.2719994654	46.0983428215	44.7849231288
75	50.2279348011	46.0983428215	45.6279297575
80	51.1002229128	47.037779039	46.4625442950
85	51.9664645639	48.5544679889	47.3949509592
90	52.9131068114	49.1985014029	48.3657985949
95	53.7788731727	50.5546259796	49.2308670194
100	54.5827679883	51.163567351	49.9714742679
105	55.3645882917	51.1354770477	50.7409197200
115	55.9572109755	51.3414395707	51.1955157584
130	57.1429131325	52.4378443233	52.3093473517
145	58.3122616511	53.2336677434	53.4162938617
160	58.9410939729	53.3549256257	53.9199997573
175	59.4699778928	53.5017990786	54.4651713792
190	59.4422756194	52.7693805071	54.2718590983
205	59.4699778928	53.7931008433	54.4758145742
220	59.6223163762	53.3329405621	54.5024297542
235	60.07678225	54.5707531622	55.2526856395
250	60.5884890656	54.9219240229	55.6817464365
265	60.6046165292	56.5796358834	55.8141783704
280	61.2332338847	57.3395372297	56.473552091
295	61.8588644606	57.0050473596	57.0487153646
310	62.6491293138	59.7561226345	58.1093811375
325	63.4268485208	59.2187058592	58.5395670176
340	63.6858554644	60.3989755099	58.8169343933
355	63.5964758158	56.8600838818	58.4031456210
370	62.6146927049	55.9997576023	57.4356942716

THIS DATA IS FROM 12 AUG 83

TIME(MIN)	TC= 79	TC= 80	TC= 53
0	29.0684715174	27.5561125234	24.7605274812
3	30.0003037018	28.4018094378	25.7790354263
6	30.6749301803	29.1168549742	26.748846163
9	31.5455030187	29.8576787529	27.6898374479
12	32.4388454943	30.6873853298	28.5606330198
15	33.1199412882	31.4089353196	29.4055218448
18	33.8751191179	32.1246217311	30.263610772
21	34.6122860716	32.8199450532	31.0716138195
24	35.2567481767	33.4442105513	31.8540545667
27	35.881136958	34.0218321636	32.5940819256
35	36.8728338354	34.8496831764	34.2594819034
40	38.2201648948	35.9121363991	37.5757123727
45	39.7960779942	37.3134000161	40.2309449799
50	41.0978134916	38.5241873884	42.4268529515
55	42.5367017477	39.7512350909	44.2952071732
60	43.7321869197	40.782539294	45.7574588251
65	44.882312391	41.8331967479	47.1580921032
70	45.78647002	42.703600134	48.3974751942
75	46.589956369	43.4895734655	49.4602709299
80	47.3403841099	44.238868737	50.4084763949
85	48.4193863894	45.3348717653	51.2801450285
90	49.2636770411	46.1548453568	52.1831770563
95	50.247444461	47.063184144	53.0684136373
100	50.9390261703	47.6922448844	53.9406017428
105	51.5291196858	48.3911464647	54.7275722225
115	51.7935219943	48.7367414745	55.4346311381
130	52.9245899846	49.7816215809	56.7359310749
145	54.0417258999	50.7332212436	57.9321316908
160	54.4725928031	51.1779951073	58.7113641985
175	54.735608604	51.6621628529	59.2448822574
190	54.3817888792	51.3651626609	59.3395238592
205	54.7612053463	51.8351456073	59.2887425103
220	54.5517432363	52.0431218612	59.4756879251
235	55.3356624137	52.3419093651	59.7271599796
250	55.6517129481	53.1611359024	60.3173389508
265	56.3134515373	49.0891677208	60.4187147462
280	57.1783487929	49.1056088191	61.0012779175
295	57.6855431044	46.3014532176	61.6637141195
310	59.1074417409	52.8975872592	62.3047223465
325	59.469862962	48.7390917237	63.0141847481
340	60.1502240638	50.0724300939	63.6098064631
355	58.8533789136	46.5967881865	63.7518344414
370	57.8244214364	48.2265016493	62.7431377907

APPENDIX F

MODEL DATA RUN 15 AUG 1983 (48.8C AMBIENT)

A. LOCATION: Root Hall, Room 107

B. CONDITIONS:

1. Backpack placed in the environmental chamber in a vertical position.

2. ambient temperature: 48.8C

C. CONDUCT OF RUN:

Part I - 8 samples were taken at 5 minute intervals.

Initial electrical readings were as follows:

resistor voltage = 3.06
load voltage = 5.17
current (amps) = 1.53
power (watts) = 7.91

Part II - 20 samples were taken at 15 minute intervals.

Electrical readings (same settings as part I) were:

resistor voltage = 3.1
load voltage = 5.40
current (amps) = 1.55
power (watts) = 7.97

THIS DATA IS FROM 15 AUG 83 -MODEL

TIME(MIN)	TC= 41	TC= 42	TC= 43
0	48.0423417034	48.2617698275	48.2409246272
5	52.6292696768	52.6408527849	50.7024765974
10	57.0951079766	55.9724462609	52.5467902545
15	57.7603061225	57.9745111823	53.8335178984
20	57.6954432734	59.2960903914	54.3244704246
25	59.5849958463	60.294489836	55.8115006254
30	60.4617159558	61.07953712	56.5071519243
35	61.8501662293	61.7210523301	57.0445403464
40	60.4017729355	62.0495808733	57.2454420579
55	61.4797830769	63.1051192634	58.2656806907
70	62.1881324611	63.7947659092	58.9121999061
85	62.659112520	64.2365346108	59.4588637627
100	57.2017779454	64.5871114141	59.7008905217
115	53.6942527516	64.6825387371	59.8644890337
130	56.7030081804	65.427402323	60.1616124957
145	55.2693082915	65.9751532211	60.5644422279
160	70.2584562937	65.9865653463	60.3083052039
175	54.2169880976	66.1735939502	60.9807875479
190	54.2725999077	66.2207521466	61.0635607705
205	64.8366645255	66.2762060998	60.9807875479
220	54.3611646605	66.3651220276	60.9853863719
235	64.9624809237	66.4107146747	61.01297 8547
250	64.9794919472	66.4357891136	61.107241869
265	65.0471055759	66.449465626	61.1831011792
280	54.5030050237	66.5474712487	61.240563723
295	54.5289330429	66.4312302049	61.3830461888
310	54.5242734904	66.4631418177	61.4083216637
325	54.5662080626	66.5406341814	61.5392769203

TIME(MIN)	TC= 53	TC= 79	TC= 30
0	47.9736664135	48.1086249672	47.9275638719
5	48.0207724131	48.1557213247	48.3017739222
10	48.1102625913	48.2216494457	48.9129825565
15	48.1550023663	48.2663818822	49.535253704
20	48.202092933	48.3158187624	50.1380755475
25	48.3480476591	48.3534819741	50.6582771529
30	48.3504014519	48.3770201717	51.121832644
35	48.4516050225	48.3934963108	51.4844493568
40	48.4257175081	48.414679193	51.7019206521
55	48.583377137	48.4805762779	52.4098137703
70	48.7480479624	48.5558775706	52.9232478536
85	48.7386395265	48.5982300209	53.242741038
100	48.8256614313	48.5982300209	53.475930567
115	48.8327166594	48.6264631777	53.6109831565
130	48.8938581881	48.645284479	53.7740515875
145	48.8585850567	48.564105135	53.9510442758
160	48.9220750689	48.6805726821	54.0721125647
175	48.9056153972	48.7040968953	54.1489309292
190	48.9525417274	48.7135062993	54.2117745645
205	48.9526417274	48.7346762704	54.260648125
220	48.3690999957	48.7511423076	54.286246873
235	48.9902599049	48.7746635071	54.3141714706
250	49.0372790199	48.8264066113	54.3327871007
265	49.1030990502	48.8663865912	54.4072435037
280	49.0866447736	48.3710899277	54.4235295374
295	49.0607870748	48.8734415808	54.4328356322
310	49.1125012708	48.8899029717	54.4281825039
325	49.1125012708	48.9087151737	54.4979740163

TIME(MIN)	TC= 44	TC= 45	TC= 46
0	48.2174113082	48.0725463971	42.7559080067
5	51.0604488026	49.2928642121	57.9632095545
10	53.0239893299	50.5597132385	57.7568021223
15	54.3967095651	51.6623383837	56.4595724485
20	55.3781652911	52.5456771229	61.6846302868
25	56.1862359448	53.3040506485	58.4181527422
30	56.8657011214	53.921560527	58.0163423745
35	57.4239694089	54.4268980192	56.0077138922
40	57.7040551246	54.7107500493	56.3344779919
55	58.6682550178	55.6171913111	62.8358404643
70	59.3147561036	56.2253206235	58.498942924
85	59.7369125105	56.6265149274	63.1427530972
100	60.0504372754	56.8976824914	56.9679768673
115	60.2370874455	57.0969198821	63.9367732209
130	60.5032982271	57.2358814439	64.9123821375
145	60.9577703157	57.4581434781	62.4622095622
160	61.0912161013	57.5575789409	63.483822829
175	61.2108309129	57.7034699204	64.2938894737
190	61.279827981	57.7728809574	59.1774016154
205	61.3350197551	57.8075833603	62.4577046352
220	61.3419133545	57.8399703663	64.5949729079
235	61.4108997974	57.8839212213	61.1035775222
250	61.4361909206	57.9139909096	56.0504524624
265	61.4660789963	57.9533104204	60.5955420365
280	61.5189540964	57.9797510141	65.2524368825
295	61.4591818859	57.9880018581	60.7519036009
310	61.5097587758	57.9810537392	62.5150136503
325	61.5764215209	58.0481286921	63.1931262741

TIME(MIN)	TC= 47	TC= 48	TC= 49
0	48.2632210794	48.0552507741	48.4356023981
5	51.7947968205	49.7871985529	51.6704553364
10	54.0493006771	51.3242510348	53.7506220504
15	55.5550834583	52.5209835478	55.1773009598
20	56.6053847565	53.3865453599	56.3081680536
25	57.4502566127	54.136708721	57.2260643111
30	58.1622250615	54.7789120299	57.3189606853
35	58.7210124047	55.2972608167	58.477670463
40	59.0209642197	55.6015403504	58.8103530423
55	60.0235193488	56.5389016951	59.7495984597
70	60.6794265079	57.1568193563	60.4271140445
85	61.1208834529	57.5788508139	60.9703923365
100	61.4425679659	57.8796083967	61.2211406400
115	61.6354933573	58.0530445157	61.3821140294
130	62.0119731437	58.7023838723	61.7530751598
145	62.3927967143	59.0717852442	62.2092566835
160	62.5257969778	59.1871743021	62.4411151035
175	62.6495975779	59.2540893051	62.5925714044
190	62.7206564365	59.3071542677	62.672872505
205	62.7596205279	59.3532937188	62.5742153003
220	62.7825390676	59.4201390251	62.6086325171
235	62.8444157446	59.4386419115	62.6351649148
250	62.3742057374	59.4709325083	62.7279296638
265	62.9062855638	59.5193649934	62.7852753079
280	62.9635666055	59.5631813257	62.8334412489
295	62.8764972124	59.5332020949	62.8861890195
310	62.936072409	59.5447327575	63.014601
325	63.0116733378	59.6093001844	63.1406914071

TIME(MIN)	TC= 50	TC= 51	TC= 52
0	47.9679052179	48.6166056613	50.9866435953
5	49.1459026629	52.2153654553	59.8222054334
10	50.5504792299	54.9726603338	63.7923481024
15	51.7845362736	56.8413476409	66.0260465546
20	52.8379127414	57.5745388631	67.4763307196
25	53.6773310447	58.5851502121	68.514591717
30	54.3828742001	59.3674330607	69.3221190109
35	54.9643431461	59.9943327911	69.8930695651
40	55.2711130468	60.2960142215	70.1760737535
55	56.2739505895	61.3655898649	71.198284123
70	56.9253079605	62.0568799715	71.6531957502
85	57.3745655402	62.5340981621	72.1736120807
100	57.6892982934	62.8711251445	72.692228312
115	57.8604771022	63.0682062731	72.497091012
130	58.0593503321	63.5857971934	72.9896608415
145	58.339043296	64.0388817711	73.491810644
160	58.5007367745	64.1966916749	73.4287341701
175	58.6416974038	64.3270239891	73.7033505415
190	58.7225321714	64.4001301732	73.7505391460
205	58.7294603328	64.4253254809	73.7978439830
220	58.7548628749	64.4298972379	73.8495240225
235	58.8056645827	64.500754866	73.8968299835
250	58.8218278136	64.5258958155	73.9350576744
265	58.8819597052	64.5830302869	73.9288102021
280	58.9280320357	64.6470142195	74.0070259391
295	58.9511173081	64.4596127906	73.1270646653
310	58.9580427034	64.625448724	73.369829895
325	59.0226757464	64.7109910984	73.9980303830

AD-A135 998 ANALYSIS AND TESTING OF THE THERMAL DESIGN OF THE ELECTRONIC PACKAGE IN T..(U) NAVAL POSTGRADUATE SCHOOL MONTEREY CA H C KEEBLER SEP 83

2/2

UNCLASSIFIED F/G 9/2 NL

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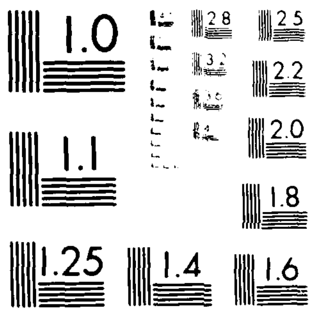

MICROCOPY RESOLUTION TEST CHART

TIME(MIN)	TC= 61	TC= 62	TC= 63
0	55.0174063642	53.7116444363	58.9812501077
5	67.3440189929	63.9949034532	71.6422990531
10	72.4016979504	58.295687299	75.4900540497
15	74.7433785399	70.3731891371	77.4437771323
20	76.2686981403	71.7548910947	78.7084904925
25	77.2617501624	72.702802511	79.6318723313
30	78.040681905	73.4532372563	80.3913702581
35	78.5281139215	73.9530837243	80.7395633027
40	78.7359306015	74.1393277362	81.0231300133
55	79.566487311	75.0480155134	81.9985095421
70	79.316320521	75.3662983146	82.5085742204
85	80.4627229022	75.9817259164	82.9500953481
100	81.4866168171	76.8714310655	83.4131455444
115	78.040681905	73.9598349234	83.3932129586
130	81.0661716609	75.634007156	83.4617971315
145	81.9112404202	77.3706396705	83.8891169954
160	81.0929479463	75.7482511349	83.7917994631
175	82.0290144837	77.4935614692	84.1280679935
190	81.7367746337	77.3012420509	84.2121207017
205	81.7912203444	77.325957288	84.2562540174
220	81.7156397063	77.2542465134	84.2519011013
235	82.2467243292	77.7039096353	84.3448118191
250	82.2900402743	77.7396892051	84.3890257063
265	81.568897304	77.155767701	84.3779800385
290	82.2911451771	77.7799386657	84.4155684833
295	80.6275547076	76.4211414047	82.4290172983
310	82.4256083994	77.8760792061	84.3824023203
325	81.8401203204	77.3952220544	84.4575763258

TIME(MIN)	TC= 64	TC= 55	TC= 66
0	51.5913212513	65.1497556172	59.3194933596
5	61.6263347329	73.7622221474	73.7077525756
10	65.4441932925	93.5245410075	77.5125090929
15	67.3821775578	85.5982975037	79.5118568475
20	68.6599964768	86.3437641446	76.4151910305
25	69.6131296277	87.7789311286	78.7576203912
30	70.3903720374	88.5392012584	73.1016545206
35	70.9381301108	88.8399634913	71.3994425[illegible]
40	71.2140795881	89.0374732151	59.8033777795
55	72.2240310492	90.0152654948	77.8332027631
70	72.8490172286	90.5392635315	84.7605472911
85	73.2300014417	91.0264755097	85.1561054324
100	73.7481053531	91.3260143221	85.4940016791
115	73.5386652521	91.5926317595	85.747850843
130	73.9304607173	91.8001527173	85.8824577361
145	74.3894754595	92.1560771475	86.2442022977
160	74.2860032401	92.1866257707	86.2816876563
175	74.6255942706	92.3197714929	86.4624663924
190	74.6885432799	92.424512754	86.5748755651
205	74.7267592142	92.461604292	86.6079[illegible]
220	74.751485793	92.5619582905	86.5822550470
235	74.8548766614	92.5488695775	86.7026671003
250	74.897575317	92.5532225131	86.7203141546
265	74.8503817317	92.6154315636	86.7974284[illegible]
280	74.9402729906	92.6470280512	85.0084415705
295	74.1127592197	29.9955498381	84.7384411774
310	74.8953290434	92.5734094698	86.7533534877
325	74.9357736621	32.7059155496	86.8789343915

TIME(MIN)	TC= 67	TC= 68	TC= 69
0	48.3495146664	54.4364562752	48.3548[illegible]
5	48.5141169617	50.347352178	53.369645[illegible]
10	48.6434128947	54.2114087933	56.7915614524
15	48.7444777157	65.6379196012	58.93880356[illegible]
20	48.8079275698	68.1589996149	60.4142[illegible]
25	48.8690205417	69.1814452804	61.478565[illegible]
30	48.918359934	70.0094497922	62.3134509927
35	48.9559489953	70.5872242751	62.952016[illegible]
40	48.9506472357	70.9770297527	63.299[illegible]
55	49.0563555642	71.3060402032	64.3506[illegible]
70	49.1555974068	72.5812563094	65.0241[illegible]
85	72.0762573091	72.9851290324	65.4649[illegible]
100	49.2072593994	73.3887140081	65.839648[illegible]
115	49.2236962345	73.4292830404	66.0337745[illegible]49
130	49.2589165682	75.0699752009	66.1775142[illegible]
145	49.2683082626	75.5799338741	66.5245[illegible]
160	49.3129166043	75.5507410605	66.602075[illegible]
175	49.3316380309	75.5507410505	66.3050[illegible]
190	49.2575214108	75.5775883242	66.387[illegible]
205	49.371606383	75.6270884535	66.932755[illegible]
220	49.3880383976	76.0356041533	66.9737927565
235	49.4152064308	75.8291369585	67.0125471[illegible]
250	49.4906611343	75.302201142	67.046729982[illegible]
265	49.5288642369	75.9054484465	67.0900450[illegible]
280	49.5312110308	76.0266288202	67.1151[illegible]
295	49.3152643437	75.0812125396	67.0239443[illegible]
310	49.3316980309	75.3560715482	67.05535[illegible]
325	49.3504787903	75.972773944	67.1675306056

TIME(MIN)	TC= 70	TC= 71	TC= 72
0	48.865428116	48.0368813376	55.103724146
5	55.1354001523	48.0840124923	65.8104593379
10	58.8636383767	48.1405645373	69.0250598208
15	61.1179154116	48.1688383757	70.4368145135
20	62.5676777787	49.1947547823	71.4634763419
25	63.6612012725	48.2253816361	72.3530[illegible]73
30	64.5034314515	48.2442281629	73.0992752351
35	65.1365864779	48.2489396809	73.5384777989
40	55.4677462765	48.2536511567	73.7748266401
55	66.5444242903	48.2795635539	74.7418005976
70	67.2368257798	48.3525829589	75.3340729649
85	67.7032773864	48.3308457379	75.8193455099
100	68.0625333614	48.3832009652	76.1153293566
115	68.2148092481	48.3879112929	76.3170504844
130	58.6691285621	48.4067521959	76.4514939445
145	69.0822530269	48.413817368	76.7449234155
160	69.1752793439	48.4208824493	76.8524032929
175	69.3295343586	48.4467869706	76.9956793836
190	69.4111823538	48.4491418665	77.0629298857
205	69.4520020896	48.4703354782	77.11206668[illegible]
220	69.5313656673	48.4821093508	77.1389219465
235	69.5495044063	48.5056563436	77.1836780347
250	69.5767114542	49.54803839	77.2015795295
265	69.619786725	48.5833542672	77.2329058520
280	69.6809934991	48.5857085784	77.2754175157
295	69.4338603355	48.6021884745	75.9494167117
310	69.6084514366	48.6068969256	77.2575132373
325	69.6945941376	48.6304385765	77.3492463815

APPENDIX G

MODEL DATA RUN 15 AUG 1983 (37.7C AMBIENT)

A. LOCATION: Root Hall, Room 107

B. CONDITIONS:

1. Backpack placed in the environmental chamber in a vertical position.
2. ambient temperature: 48.8C

C. CONDUCT OF RUN:

Part I - 15 samples were taken at 5 minute intervals.

Initial electrical readings were as follows:

resistor voltage = 3.27
load voltage = 4.72
current (amps) = 1.64
power (watts) = 7.72

Part II - 24 samples were taken at 30 minute intervals.

Electrical readings (same settings as part I) were:

resistor voltage = 2.8
load voltage = 4.73
current (amps) = 1.40
power (watts) = 6.62

THIS DATA IS FROM 15 AUG 83 -MODEL 2

TIME(MIN)	TC= 41	TC= 42	TC= 43
0	37.0855553597	37.4556497504	37.0906383149
5	44.21953431	41.4458650994	39.3736976316
10	44.0841999571	44.3479901065	41.3922475246
15	51.6442112222	46.0993107425	43.0211119973
20	46.1745238767	47.2393783288	44.0756566808
25	51.7987542923	48.0522537493	44.8202363022
30	49.210309334	48.9791357002	45.5320804294
35	50.624549105	49.6415791671	45.8510452908
40	51.4708842904	49.9701570849	46.0210839623
45	55.8251100514	50.2446050619	46.231197793
50	55.4926254515	50.5142294455	46.4577472558
55	56.2177925048	50.7860659036	46.667594055
60	49.7463633561	51.0249847819	46.7808905013
65	51.8900549133	51.2193225181	46.9826425541
70	52.032828261	51.3691287913	47.20515986
75	49.4760507102	50.708746645	46.8799182912
105	41.6852500496	51.3082752562	47.3088329255
135	43.057396597	51.5118744751	47.3135440791
165	43.4949793101	51.6382090233	47.3724346346
195	70.12245019	51.7434659646	47.4995151227
225	57.5425227602	51.8463646727	47.7727216891
255	50.678509482	51.9292023775	47.9221487708
285	52.3416545102	51.9772992449	47.8786314475
315	50.678509482	51.9843127207	47.7915515753
345	51.1357875932	51.9585961852	47.7209361900
375	51.215479362	51.9492444205	47.6903330846
405	52.0398489514	51.9422304943	47.6079327799
435	50.6222028818	51.9258643238	47.5961602503
465	51.7940718032	51.9094976739	47.6032298022
495	52.2246951181	51.9282023775	47.7515372994
525	52.0819712252	51.9305404215	47.695041619
555	50.5987401002	51.919850104	47.6456031544
585	50.612817389	51.8978069158	47.6079327799
615	51.0631174354	51.9024832483	47.6125417173
645	68.6515554292	51.9305404215	47.6691458329
675	42.2597897137	51.9749613966	47.9280490521
705	50.6714714716	51.988988309	47.7986126[illegible]
735	42.2979114937	52.0404174483	47.7962589465
765	41.0718817606	44.9237079502	43.5147458379

TIME(MIN)	TC= 44	TC= 45	TC= 46
0	37.1365440714	36.8565315317	39.783042954
5	39.7179571843	38.2271578709	38.0019489225
10	41.5177356255	39.6037430532	41.0346370537
15	42.8481554434	40.7119949527	45.9510374214
20	43.8218634055	41.5321489804	48.6982223009
25	44.5403403535	42.2035506474	48.1273041075
30	45.2460290378	42.634044737	44.9211604510
35	45.8397081305	43.0855752052	45.7480487575
40	46.1752881958	43.4583974243	47.0378825369
45	46.456354959	43.7525742965	49.1442129932
50	46.7013748358	43.9946210093	49.8664302777
55	46.926051551	44.2127549291	51.1467922491
60	47.1194776339	44.3952561365	49.1535984541
65	47.2892589929	44.532684201	49.2615193841
70	47.4307032748	44.5274419054	45.098455257
75	47.0274908444	44.4473681446	46.0612091142
105	47.4118461441	44.5990163277	49.8523729347
135	47.553258833	44.7624431169	47.8475052429
165	47.6592944488	44.8476697905	51.254331505
195	47.7794340039	44.9660658067	49.9882748292
225	47.8548175713	45.0418129572	51.5067244401
255	47.9066313159	45.0820493479	45.3731552573
285	47.946665865	45.1317490234	51.5441179699
315	47.963149832	45.1388485071	50.8521230937
345	47.932536357	45.112816348	57.1771910129
375	47.9207514897	45.100983092	50.0404256924
405	47.9136964482	45.093883015	46.0005930296
435	47.8995660929	45.0867829456	46.0171106461
465	47.8901456542	45.0867828456	47.9486252549
495	47.9231164833	45.1104497174	48.014460974
525	47.9372462333	45.1293824749	46.1232832063
555	47.9278264403	45.1199161784	45.1409976354
585	47.9042762517	45.1080830765	45.240250168
615	47.9113414142	45.1151829684	51.3992432879
645	47.9419560693	45.1435815115	48.5244242935
675	48.0008256156	45.1956419481	48.6958740396
705	48.0337998091	45.2145717472	49.5288877168
735	48.0455622565	45.2405991479	49.5030946296
765	43.3637297491	42.5555824957	38.3131715242

TIME(MIN)	TC= 47	TC= 48	TC= 49
0	37.2691517576	36.9170773633	37.3456732931
5	40.3667168953	38.9023725377	40.2460022045
10	42.4044475686	40.2967158988	42.5078518317
15	43.8234740536	41.5272968017	44.2175783358
20	44.8699544665	42.2723792338	45.2857901039
25	45.6093085387	42.8738810782	46.0259131943
30	46.341592568	43.6669331975	46.7933521186
35	46.968733196	44.1934094136	47.1519087021
40	47.3291431155	44.3711575562	47.2674460362
45	47.6092961504	44.6104331574	47.481951075'
50	47.856372525	44.8448634423	47.7081513237
55	48.0962846046	45.0460706834	47.9130649895
60	48.2914307475	45.2377254388	48.0331513340
65	48.4724087752	45.4269673119	48.25441837
70	48.6039922215	45.5452047079	48.4944152302
75	48.1197998154	45.2252696183	48.0355057068
105	48.6016427944	45.4506172415	48.5320534733
135	48.7496376811	45.5901290108	48.5602797215
165	48.8529753911	45.7366941286	48.6661153237
195	48.9703824415	45.8619503391	48.7977935131
225	49.0478572252	45.9375676393	49.0728056356
255	49.0995011244	45.9800960861	49.0963046
285	49.1487931082	46.0067955353	49.1902904747
315	49.1652223027	46.0486071804	49.0916045687
345	49.1300157227	46.0131714794	49.0140538553
375	49.1088904092	46.0013590687	48.983500462
405	49.1159322691	46.0060840536	48.915336806'
435	49.0995011244	45.9848212548	48.8871286962
465	49.0901116817	45.9824586805	48.8777256729
495	49.1206267931	46.0178963722	49.0469556214
525	49.1323629304	46.0391578847	48.98565073
555	49.1182795361	45.9611949527	48.8683224895
585	49.0924590572	45.9493814287	48.8448138311
615	3.1112377057	46.0462448718	48.9317908721
645	49.127668505	46.0745919015	48.999952499
675	49.1863459853	46.1360054258	49.2537219147
705	49.2074683691	46.1454530482	49.1245020393
735	49.2332835313	46.1332419064	49.1245020393
765	43.6670403434	42.8406139302	43.7004817102

TIME(MIN)	TC= 50	TC= 51	TC= 52
0	36.7228959512	37.6037868249	40.567320386
5	37.8081852392	40.3732221136	48.5519714776
10	39.1568847999	43.1288217897	52.5385167207
15	40.4329583555	44.7575358879	54.0861039647
20	41.4916487812	45.3288227088	55.1510929887
25	42.3199768365	46.5913926045	55.9056011338
30	42.9879904941	47.3246286292	56.2697270414
35	43.5434785325	47.9862928443	56.7193436125
40	43.9348902179	48.2709626963	57.1014697121
45	44.2241163214	48.5319786863	57.3977302553
50	44.4894999853	48.7834708101	57.5290756154
55	44.7026609948	49.0137038719	57.915315754
60	44.9039031793	49.213327455	58.1515798201
65	45.1287330665	49.5794988502	58.3410342369
70	45.2801452131	49.710885912	58.4934811333
75	45.1132684129	49.3166311142	57.4347519968
105	45.2422961125	49.6217338062	58.3964741787
135	45.2700263172	49.7501480242	58.6274160533
165	45.457527924	49.8586591078	58.7125409042
195	45.587571999	49.9899799829	58.7944002529
225	45.6863575629	50.0814172193	58.8836523353
255	45.7294030033	50.1212597583	58.9944215765
285	45.7979414791	50.1869029931	59.0336473441
315	45.7813984942	50.1939346648	59.0474910556
345	45.745947559	50.1447110909	59.012881149
375	45.7317565419	50.1376787951	59.0013440405
405	45.7175851573	50.1095487206	58.989906715[illegible]
435	45.6939486994	50.0931388516	58.9828842938
465	45.6868575629	50.075728497	58.9598085606
495	45.7435840817	50.1353346767	58.9644237537
525	45.7530379298	50.1400229035	58.9851917164
555	45.7483110251	50.1139255706	58.9644237527
585	45.7199487469	50.090794545	58.9482703901
615	45.7199487469	50.1142371554	58.9182700578
645	45.7554013663	50.1400229035	58.9413473761
675	45.8546564846	50.2337791215	58.9874992298
705	45.8664713715	50.2290916869	58.9621161666
735	45.8782860034	50.2478411879	59.0474910556
765	43.2610122145	44.2317622515	44.9956272696

TIME(MIN)	TC= 53	TC= 77
0	37.6031270633	36.6560563095
5	38.1743201914	37.0233223305
10	37.763987373	37.4897590887
15	37.8526003616	38.0056707581
20	37.8984009473	38.5210671371
25	37.792793567	38.9569630299
30	37.8239979547	39.3374791563
35	37.84800007	39.6483899336
40	37.7735899464	39.9041567151
45	37.7663884078	40.1239593871
50	37.7879927275	40.2911581254
55	37.7711894445	40.4535192637
60	37.583916511	40.5609369156
65	36.8389653932	40.5871912571
70	36.487750087	40.5513995579
75	36.7379550141	40.4673429709
105	36.8918679128	40.4964539292
135	37.1130382299	40.6134443244
165	37.0553505006	40.5893094492
195	37.1490897739	40.3067224691
225	37.194751504	40.3568201795
255	37.3317123435	40.3092984475
285	37.240409253	40.9307653413
315	37.2452151061	40.9259949956
345	37.2043639931	40.9069121638
375	37.2500209102	40.3949967048
405	37.228394445	40.3021426242
435	37.228394445	40.3925011763
465	37.3293103211	40.3212246057
495	37.3245052434	40.3403059065
525	37.2740492701	40.3546154305
555	37.3509325253	40.3713115632
585	37.3461277466	40.9498453005
615	37.2235884427	40.347461219
645	37.4422169828	40.9665415795
675	37.3941745628	41.0251633115
705	37.4398149662	41.0380862587
735	37.5430917544	41.0786249264
765	35.1239498263	40.0403560198

TIME(MIN)	TC= 61	TC= 62	TC= 63
0	43.6225380124	42.4124141247	48.0212538853
5	54.1928967898	51.2220991025	57.5944917117
10	56.0962940121	52.925804213	60.3480844651
15	59.1035004258	55.5030886086	62.4312823767
20	61.6902991481	57.9623314662	63.8530990844
25	62.8552555372	58.8821109267	64.8996696809
30	63.6421049835	59.5828255612	65.5435612647
35	64.2195151849	60.2774488057	66.1664225095
40	64.3981204592	60.5146652416	66.6222363227
45	64.3981204592	60.5515056303	66.9342636228
50	64.9175938885	61.0210142761	67.2074354374
55	65.585130033	61.6257489083	67.4691054382
60	65.3318327953	61.8601144994	67.6874534497
65	66.0030921945	62.036974639	67.8579812032
70	66.124085032	62.1540860101	68.0102773627
75	64.3179838944	60.7425773515	66.7930748251
105	65.0182308301	61.2234294714	67.9398168958
135	65.409176591	61.5582918577	68.1625339557
165	65.9619945487	62.0553466178	68.28294773[illegible]
195	66.0751474903	62.1586781299	68.3624527098
225	66.4777873806	62.5190459183	68.4146929705
255	66.6853445983	62.700292718	68.5237011403
285	66.7674346899	62.7713993963	68.5691152043
315	66.7697148037	62.7328673985	68.5668446131
345	66.7560339806	62.7576374942	68.5464086257
375	66.7172598999	62.7255251185	68.5032536512
405	66.6830541525	62.6934109636	68.507805377
435	66.6488563922	62.6590009656	68.4873673342
465	66.5918389837	62.6154120348	68.4828254562
495	66.4960371416	62.5488752387	68.4753125583
525	66.3294868157	62.3997132729	68.4669285734
555	66.3408958953	62.3997132729	68.4533023472
585	66.2678739095	62.3469236316	68.4396757925
615	66.3112318213	62.383647385	68.401065525
645	66.2701559856	62.3584000891	68.3987942533
675	66.3157956237	62.4180737419	68.4497601995
705	66.1583237093	62.2849471497	68.4305912569
735	66.3819667238	62.4635620304	68.507805377
765	45.3803356381	45.1715143013	45.0496088416

TIME(MIN)	TC= 64	TC= 65	TC= 66
0	41.0135475522	53.6382928171	38.1731834565
5	48.9054496252	65.4465971159	39.7975778125
10	52.0194009048	69.1421598549	40.0175854015
15	53.625823893	70.9473178816	40.1084314415
20	55.0765144664	71.3415261339	40.2227213524
25	56.0709744135	72.7717619453	40.2566205147
30	56.7948060539	73.1143454515	40.2709591950
35	57.4227688153	73.5648112974	40.2948561144
40	57.3798224505	73.3844041314	40.2327213524
45	58.1795711795	74.1656497647	40.2585654410
50	58.4639794022	74.4197539229	40.2731291902
55	58.7523666423	74.626554035	40.2924664241
60	58.3815614293	74.3035699151	40.2791291412
65	59.1732247712	74.9770525559	39.5509625215
70	59.3140447060	75.1454975092	39.2950425517
75	58.2558897903	73.7944171038	41.3214090479
105	59.1898862043	75.1791688531	41.5741624071
135	59.4317527972	75.3722379129	41.7432905404
165	59.5655973799	75.4620160939	41.7075441745
195	59.6532551023	75.5517807232	41.8530059746
225	59.7455223843	75.5607564454	41.8124992157
255	59.3515113441	75.6300136609	41.8601518352
285	59.9092501297	75.5662109754	41.8482406414
315	59.9092601297	75.5684544855	41.8209441371
345	59.9977308277	75.6415318045	41.8053517275
375	59.8608355405	75.6146079042	41.8124992157
405	59.8446930992	75.6101204613	41.8029571515
435	59.8377747704	75.5289017127	41.7996701054
465	59.8262440385	75.5764636249	41.8553086055
495	59.8354686422	75.5507564455	41.8362271213
525	59.8285502019	75.5809510142	41.8363271213
555	59.9147100699	75.540560891	41.8404752554
585	59.7370373009	75.524852751	41.9404752554
615	59.7324251258	75.5126324175	41.7208598827
645	59.7893441245	75.511388321	41.3696842152
675	59.8400808893	75.5472929118	41.8506223114
705	59.8239378619	75.5742197676	41.8530059744
735	59.8977308377	75.6079757385	41.8292455242
765	45.2414224891	44.9529418505	36.4021270082

TIME(MIN)	TC= 67	TC= 68	TC= 69
0	45.395208997	44.4571194196	37.5832753645
5	38.5487756192	55.1603900256	42.453[illegible]
10	42.6116859684	58.3972974901	45.3295[illegible]
15	44.4883932525	60.9578708934	47.3281[illegible]
20	41.6766290704	59.8815371262	49.1547[illegible]63
25	46.5143351283	58.2272570767	49.397[illegible]
30	49.4279426504	58.1625706069	50.24[illegible]45
35	42.3977400955	58.1440589288	50.6896[illegible]
40	43.1176862552	58.1486868299	51.0930[illegible]54
45	41.7363468357	58.3869779045	51.4493[illegible]
50	51.255756117	58.6274911074	51.7046[illegible]
55	51.8870754755	58.8860708172	51.9622[illegible]
60	42.6306992546	59.1081825495	52.1345[illegible]
65	43.4405181573	59.3045052393	52.2717[illegible]
70	41.0574520393	59.4799854353	52.5330952205
75	41.4029622302	58.4077947055	51.[illegible]
105	44.1898842075	59.3068155275	52.554[illegible]
135	42.3168939534	59.5050792537	52.7294[illegible]
165	41.1813847905	59.6484869608	52.8246[illegible]
195	41.1361538615	59.747717983	52.8351[illegible]
225	53.9025058917	59.8169387056	52.9912[illegible]
255	34.4230072534	59.8975856011	53.0720[illegible]
285	41.2314254179	59.9599642567	53.122[illegible]
315	45.3876666218	59.983034132	53.129[illegible]
345	33.0162457759	59.946129254	53.1104[illegible]
375	43.5188292024	59.934594662	53.1347[illegible]
405	44.6825728957	59.9207540429	53.0822[illegible]
435	40.3191254586	59.8930713005	53.0720[illegible]
465	41.0836709779	59.8930713005	53.0590[illegible]
495	42.5301114887	59.8907646664	53.0226[illegible]
525	44.9145502249	59.8834579622	53.0893[illegible]
555	44.1045657188	59.8515453173	53.0820[illegible]
585	34.6981107256	59.8215531213	53.0560[illegible]
615	51.735151108	59.8561600536	53.054[illegible]
645	45.3663852153	59.8700022385	53.0636[illegible]
675	44.2557115933	59.9299811599	53.12675[illegible]
705	45.7351453665	59.9207540429	53.1037[illegible]
735	54.5541056072	59.3853407223	53.1351522[illegible]
765	38.7618763202	45.3908196379	44.955050736[illegible]

TIME(MIN)	TC= 70	TC= 71	TC= 72
0	38.1335143984	44.5161103723	44.5168852959
5	44.2023628536	52.3400127074	52.664967741
10	47.9077260203	55.8341599238	55.4220559551
15	50.0185803802	57.5674422551	57.024934074
20	51.1042169709	58.8253734857	58.1542042323
25	51.9133652164	59.7941342795	59.0296900549
30	52.2546307083	60.3994411329	59.5664294211
35	52.7427920422	60.9491419741	60.1734452914
40	53.0998842924	61.4000581522	60.562522456
45	53.4101129514	61.723355035	60.675625327
50	53.6963634817	62.0144784605	61.1355602905
55	53.9508530708	62.2466137	61.358536362
60	54.1721270911	62.4327096917	61.5470248575
65	54.3537393795	62.5980799124	61.719409741
70	54.5352920578	62.7519220432	61.3664230971
75	53.7364841462	61.5557521963	60.336514518
105	54.5329658171	62.7973389092	61.3802091459
135	54.7191146837	62.9639893542	62.0455550454
165	54.8214703423	63.0517819009	62.1625430422
195	54.9261330378	63.1573252521	62.2729206797
225	55.0005480215	63.2109106215	62.3222239295
255	55.0703031496	63.2682917068	62.369222174
285	55.119126606	63.3141360636	62.4229165569
315	55.1237752095	63.3141360636	62.4220902052
345	55.1121520853	63.2965118899	62.401350412
375	55.0865731047	63.256792546	62.3729129913
405	55.0703031496	63.245322157	62.369222174
435	55.0656530762	63.2476170531	62.3554528018
465	55.0610029644	63.231545983	62.346274038
495	55.0703031496	63.23385354	62.364602419
525	55.072628172	63.2384414142	62.3715100175
555	55.072628172	63.23385354	62.3347991175
585	55.0517026259	63.2246776322	62.3397991192
615	55.0251259038	63.2017272037	62.3485689925
645	55.0377518304	63.1925613241	62.341684101
675	55.0842531399	63.2590862964	62.4017504022
705	55.1051774793	63.2705555114	62.4288366799
735	55.1446991108	63.2934930579	62.4449482517
765	45.4552682996	44.5757934853	44.573741014

TIME(MIN)	TC= 78	TC= 79	TC= 80
0	36.7528874126	36.8704290919	36.6721180994
5	37.5510209709	37.3631727522	37.1837654592
10	38.5781529864	37.4472534414	37.3819757034
15	39.5291045693	37.5577290023	38.6080009391
20	40.3565032533	37.622193548	39.2206057361
25	41.0346787071	37.6730034958	39.7680602735
30	41.595193601	37.6922117953	40.2194424665
35	42.0598559492	37.7066175415	40.5988820029
40	42.421774955	37.5778056341	40.3755365085
45	42.7097071126	37.6874037798	41.0948577795
50	42.9451732407	37.5970137479	41.3164579697
55	43.1591439328	37.7066175415	41.4784255403
60	43.3350115964	37.6585968177	41.6046489994
65	43.484691721	37.2958984942	41.6736966552
70	43.5583235411	36.9714192126	41.7072258453
75	43.4300514507	36.334356454	41.5975056222
105	43.4989447937	36.8872521239	41.6356024651
135	43.6408296506	37.0195029032	41.7665399109
165	43.7506859841	37.0243110294	41.8569971301
195	43.8646448244	37.1589206435	41.9831120139
225	43.9216147256	37.1348857494	42.0211016372
255	43.9762052429	37.1329544351	42.0820390472
285	44.0212975961	37.178147765	42.1092072553
315	44.0260439407	37.1537274901	42.0973128274
345	44.0070583122	37.1348857494	42.1062284711
375	43.9833253383	37.1444998394	42.0687548895
405	43.9856986226	37.1541137529	42.0592485749
435	43.9714584603	37.1541137529	42.04259462
465	43.9833253383	37.2190030558	42.0877970199
495	44.0094315523	37.2165998915	42.1258532551
525	44.0212975961	37.2238093512	42.1282380552
555	44.0070583122	37.2358248969	42.1187227999
585	44.0094315523	37.257452135	42.1258592553
615	44.0070583122	37.1901643577	42.1306158466
645	44.0165512099	37.2766756921	42.1211016222
675	44.0301155126	37.3127178679	42.2230814972
705	44.1067254209	37.3103151333	42.2281382293
735	44.130452976	37.3679777251	42.2566777417
765	42.1551214834	36.0955224177	40.9422938119

LIST OF REFERENCES

1. Azar, L., A Conceptual Design of the Upgraded Logic Module, a Preliminary design concept presented to the Cdr. U.S. Army Combat Developments Experimentation Command, Ft. Ord, California, 15 July 1981.

2. Commander, Instrumentation Command, U.S. Army Combat Developments Experimentation Command (CDEC), Letter to Chief of Staff, U.S. Army CDEC, subject: Request for Upgraded Logic Module, 12 December 1980.

3. BDM Scientific Support Laboratory Specification #28A600034, Development Specification for an IDFSS Upgraded Logic Module, 12 December 1980.

4. Rome Air Development Center, RADC-TR-82-172, RADC Thermal Guide for Reliability Engineers, by G. N. Morrison and Others, 23 January 1982.

5. Kraus, A. D. and Bar-Cohen, A., Thermal Analysis and Control of Electronic Equipment, Hemisphere Publishing Corporation, 1983.

6. Incropera, F. P. and Dewitt, D. P., Fundamentals of Heat Transfer, John Wiley and Sons, 1981.

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8